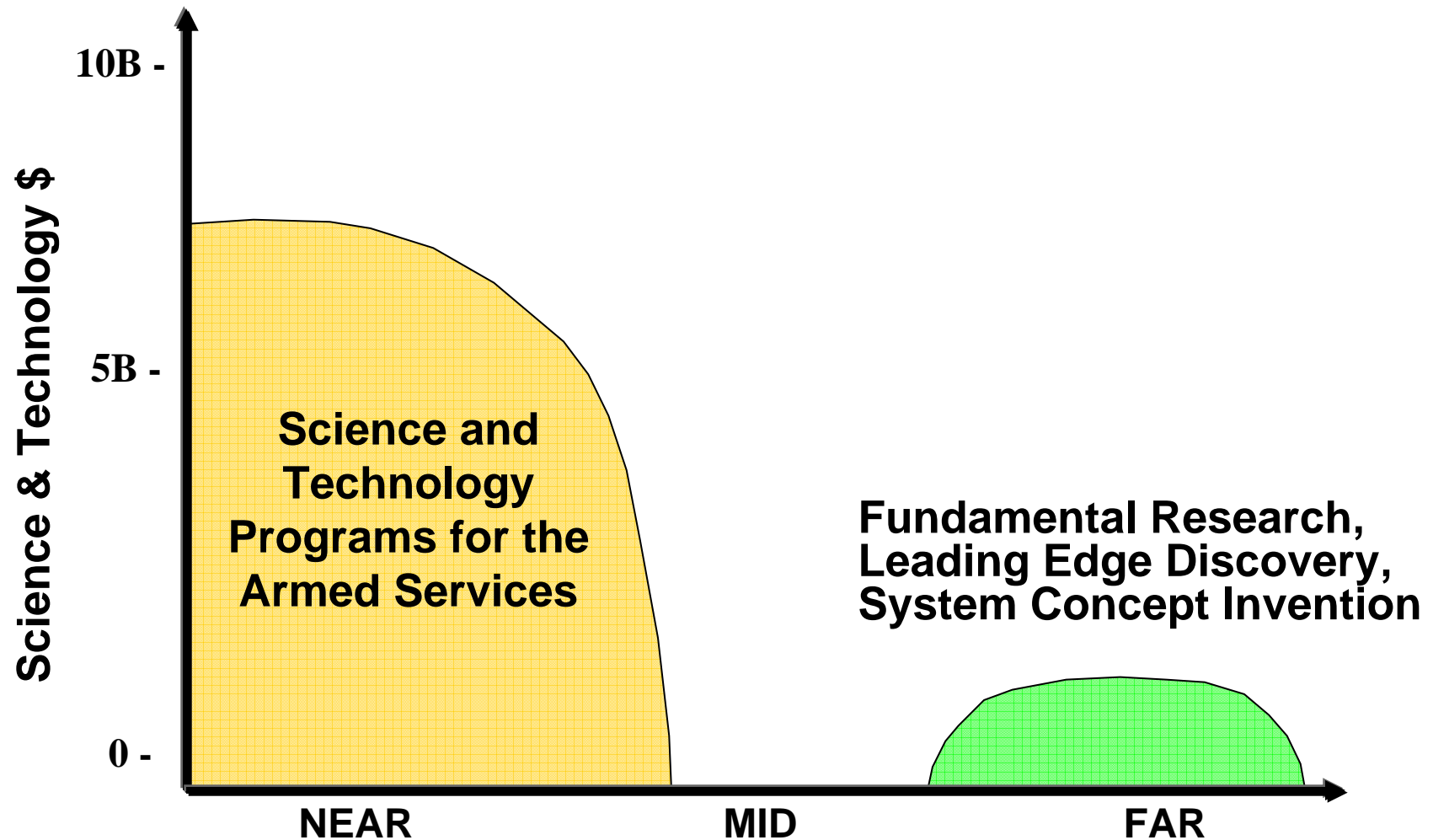


**Defense Advanced  
Research Projects Agency  
*"Bridging the Gap"***

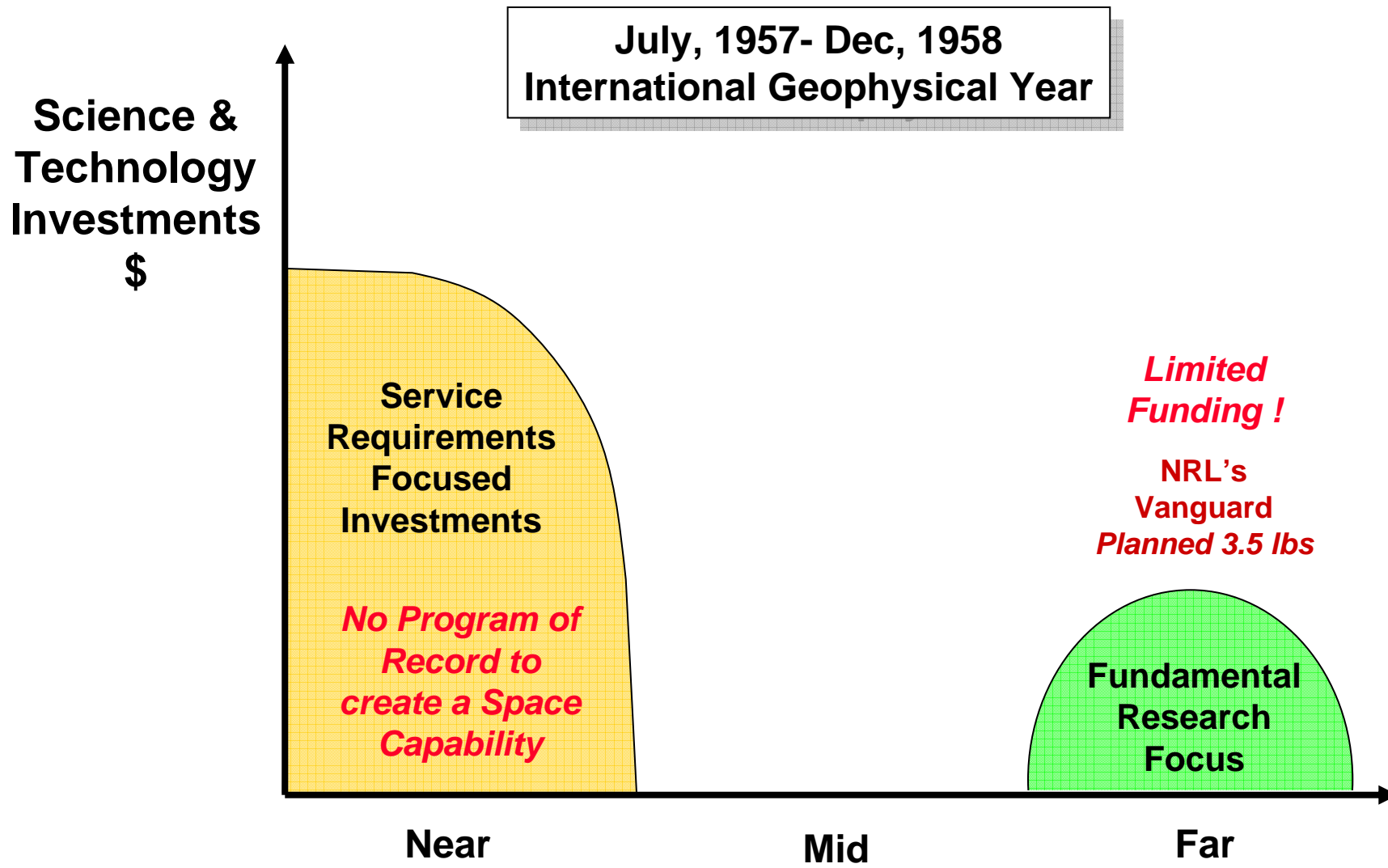
**Dr. Robert F. Leheny**  
**Deputy Director**

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE <b>05 MAR 2007</b>		2. REPORT TYPE <b>N/A</b>		3. DATES COVERED <b>-</b>	
4. TITLE AND SUBTITLE <b>Bridging the Gap</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
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9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
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14. ABSTRACT					
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16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>UU</b>	18. NUMBER OF PAGES <b>44</b>	19a. NAME OF RESPONSIBLE PERSON
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# DARPA Role in Science and Technology



# DOD Investments in Science & Technology (circa 1957)



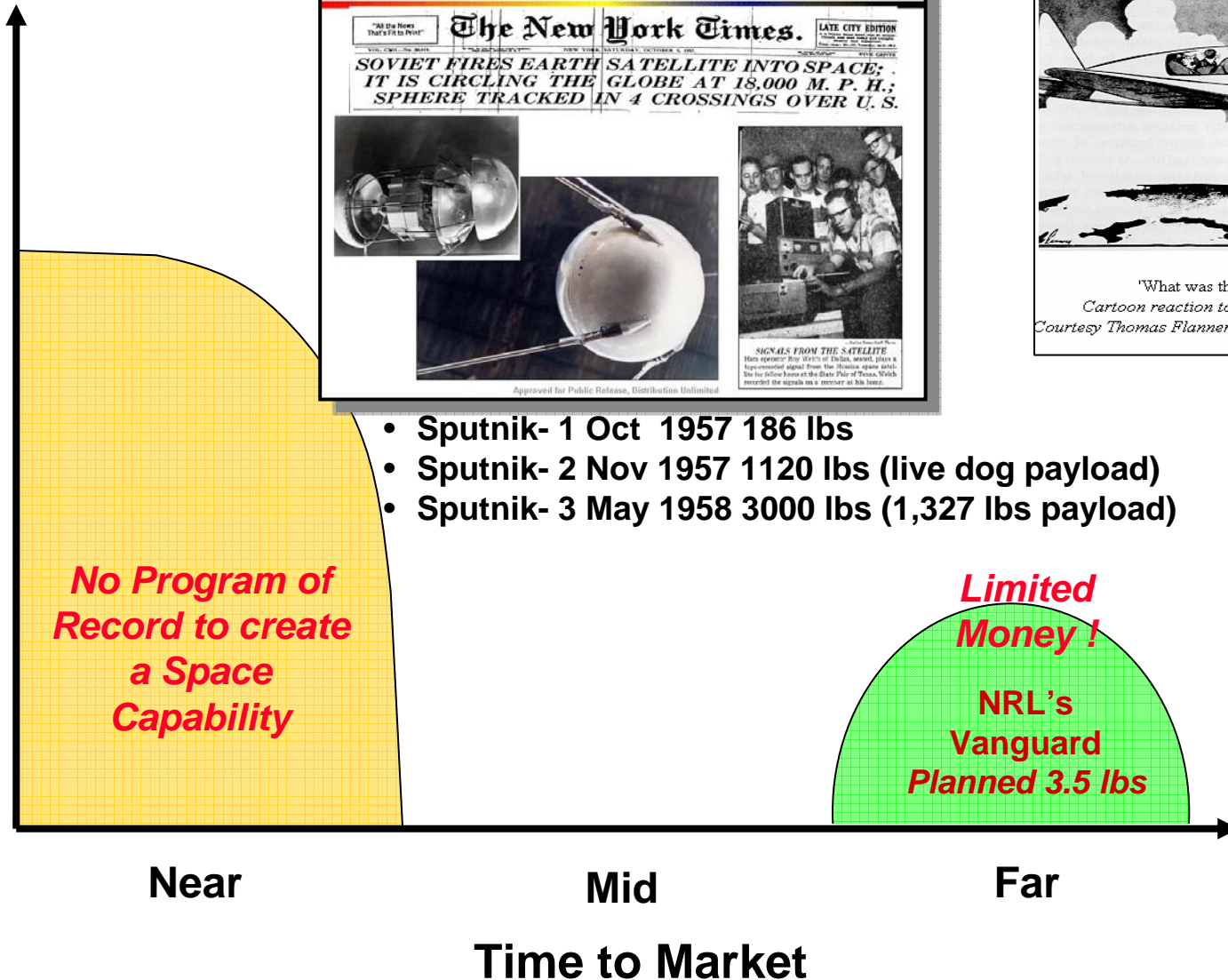


# DOD Investments in S&T

## *Sputnik- A wake-up call*



Science &  
Technology  
Investments  
\$

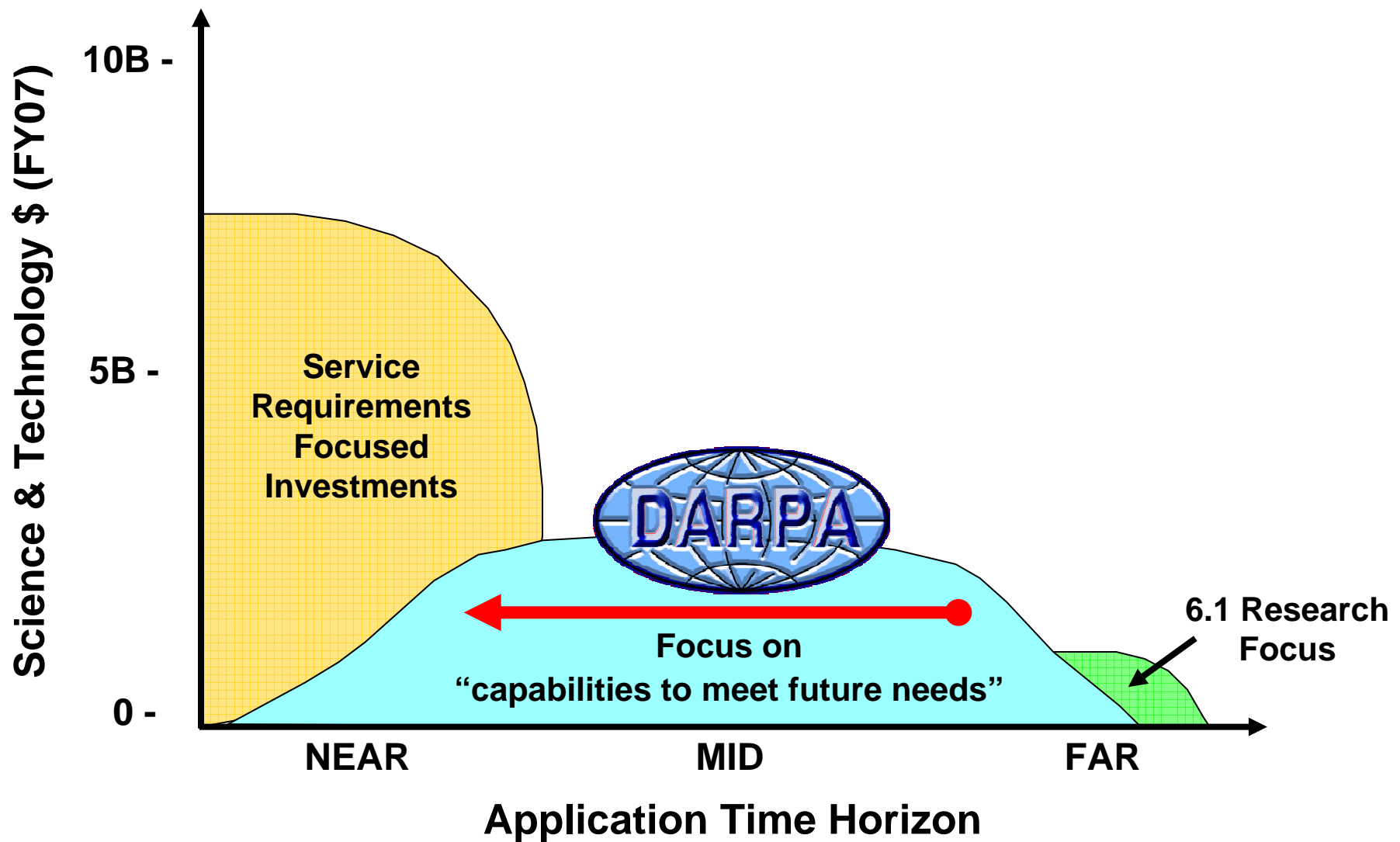


- Sputnik- 1 Oct 1957 186 lbs
- Sputnik- 2 Nov 1957 1120 lbs (live dog payload)
- Sputnik- 3 May 1958 3000 lbs (1,327 lbs payload)



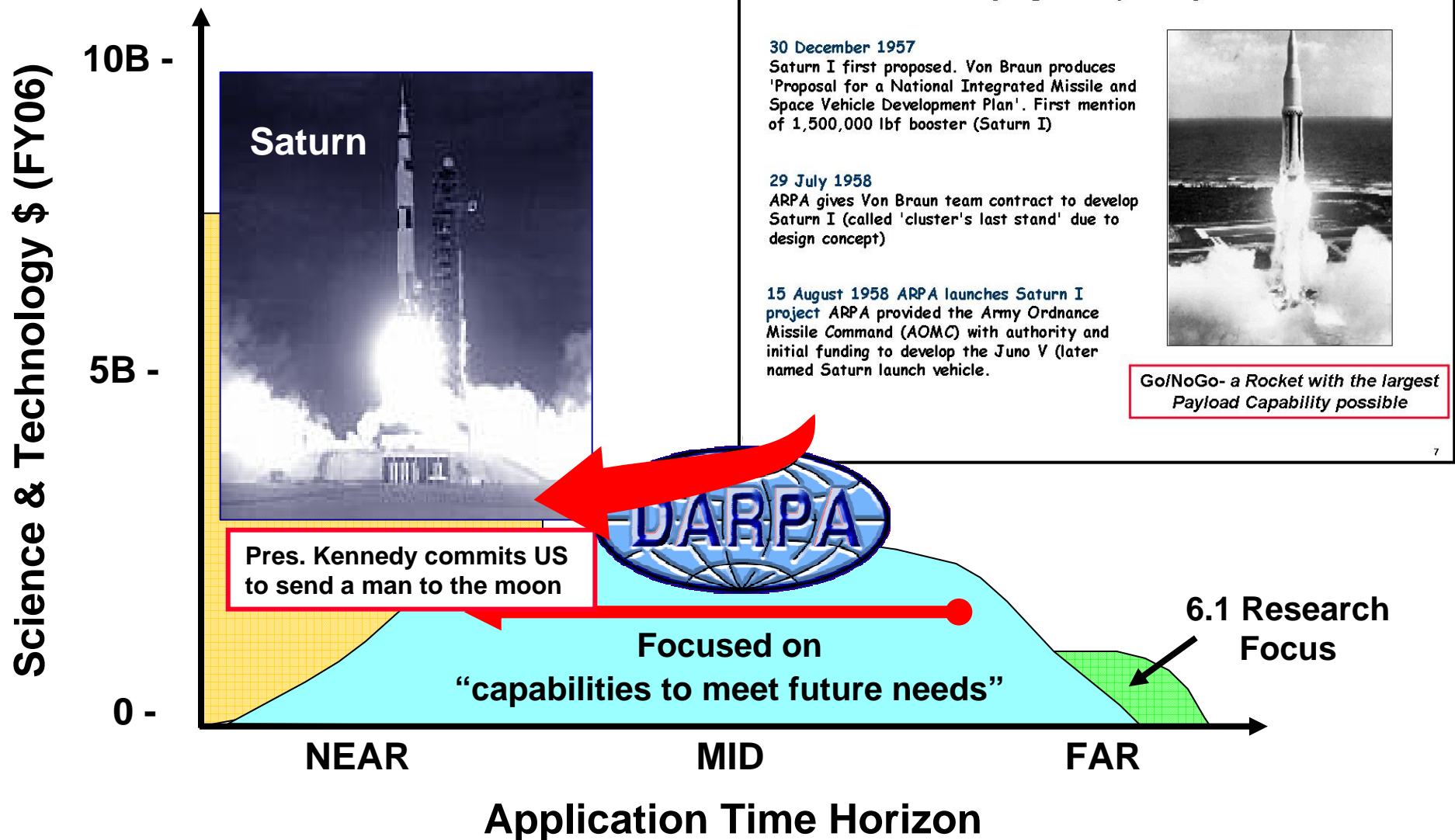
# DARPA Investments:

## *Innovation Driving New Capabilities*



# DARPA Investments:

## *Innovation Driving New Capabilities*



# DARPA Accomplishments





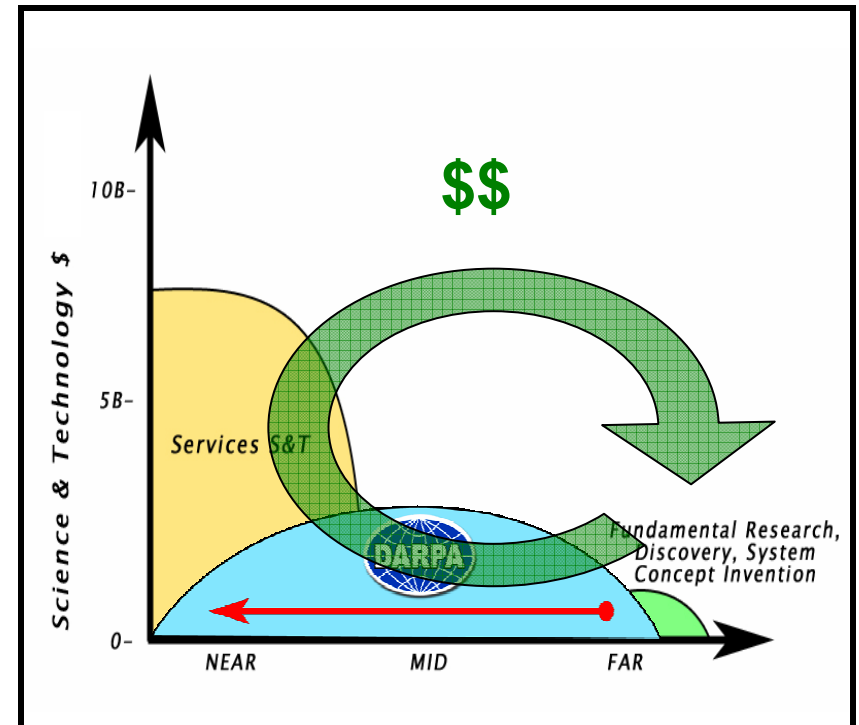
# DARPA Business Model



Projects (Programs) agency:

Typical projects are 3-5 years with multiple contracts-

- Projects are phased,
  - Well-defined milestones (Go-NoGo) for progression between phases.
  - Timing of Go/No-Go decisions are dependent upon effort and not pre-determined
- Projects with fieldable prototypes as deliverables typically require MOUs with operators (end users) to go forward to final phase.
- Funding in any technology area beyond end of project contract dependent on ideas



# DARPA Organization



**Director, Tony Tether**  
**Deputy Director, Bob Leheny**

## **Tactical Technology**

Steve Welby  
Steve Walker

Air/Space/Land/Sea Platforms  
Unmanned Systems  
Space Operations  
Laser Systems  
Precision Strike

## **Information Exploitation**

Bob Tenney  
Mark Davis

Sensors  
Exploitation Systems  
Command & Control

## **Strategic Technology**

Dave Honey  
Larry Stotts/Brian Pierce

Space Sensors/Structures  
Strategic & Tactical Networks  
Information Assurance  
Underground Facility Detection  
& Characterization  
Chem/Bio Defense  
Maritime Operations

## **Defense Sciences**

Brett Giroir  
Barbara McQuiston

Physical Sciences  
Materials  
Biology  
Mathematics  
Human Effectiveness  
Bio Warfare Defense

## **Information Processing Technology**

Charlie Holland  
Barbara Yoon

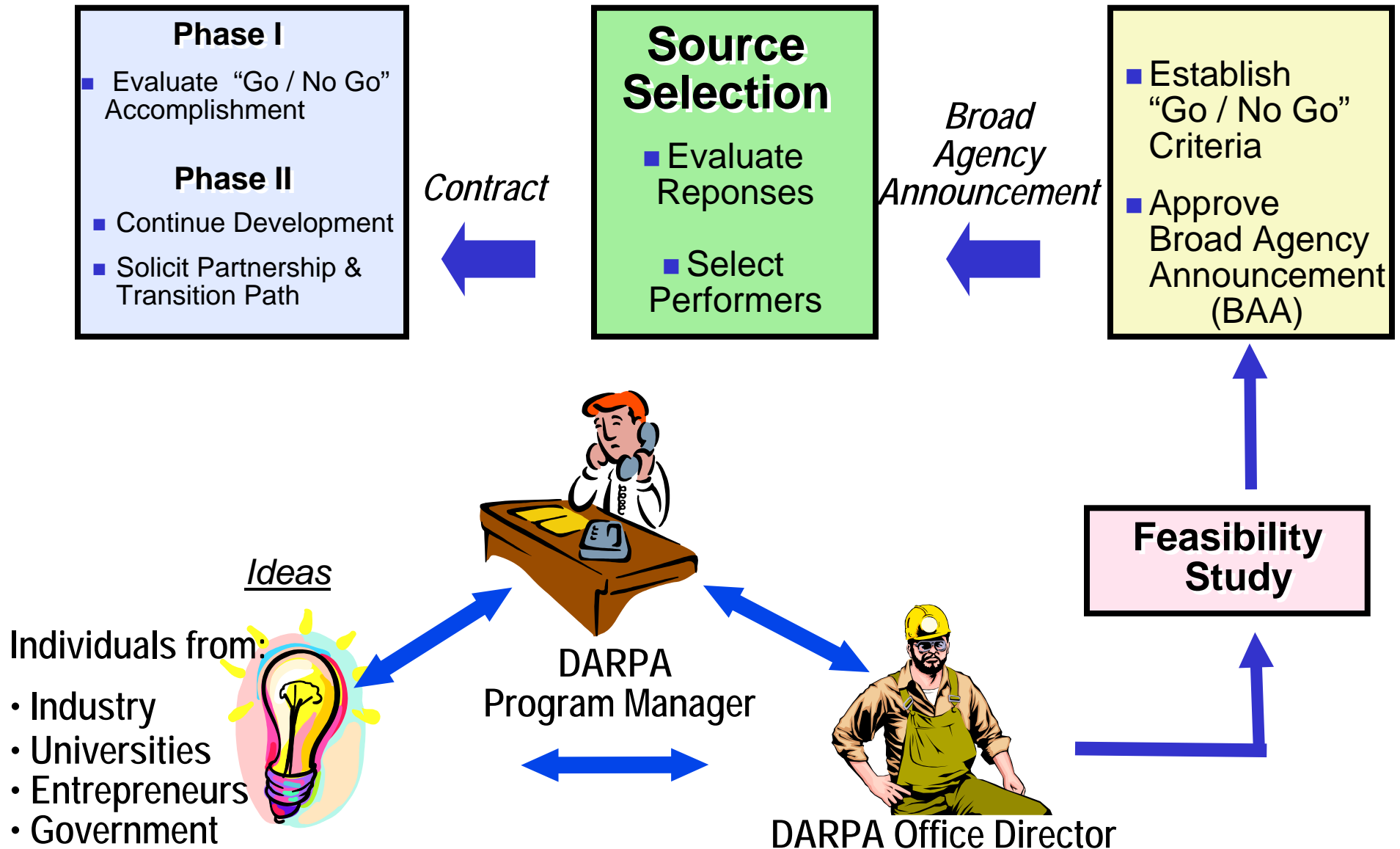
Cognitive Systems  
High Productivity Computing  
Systems  
Language Translation

## **Microsystems Technology**

John Zolper  
Dean Collins

Electronics  
Photonics  
MEMS  
Algorithms  
Integrated Microsystems

# DARPA's New Initiative Process



# DARPA's Strategic Thrusts



## *Investments Today Create Future Capabilities*

- **Detection, Precision ID, Tracking & Destruction of Elusive Targets**
- **Networked Manned & Unmanned Systems**
- **Robust, Secure Self-Forming Tactical Networks**
- **Urban Area Operations**
- **Location and Characterization of Underground Structures**
- **Assured Use of Space**
- **Cognitive Systems**
- **Bio-Revolution**
- **Core Technologies (Biology / Materials / Electronics / IT)**



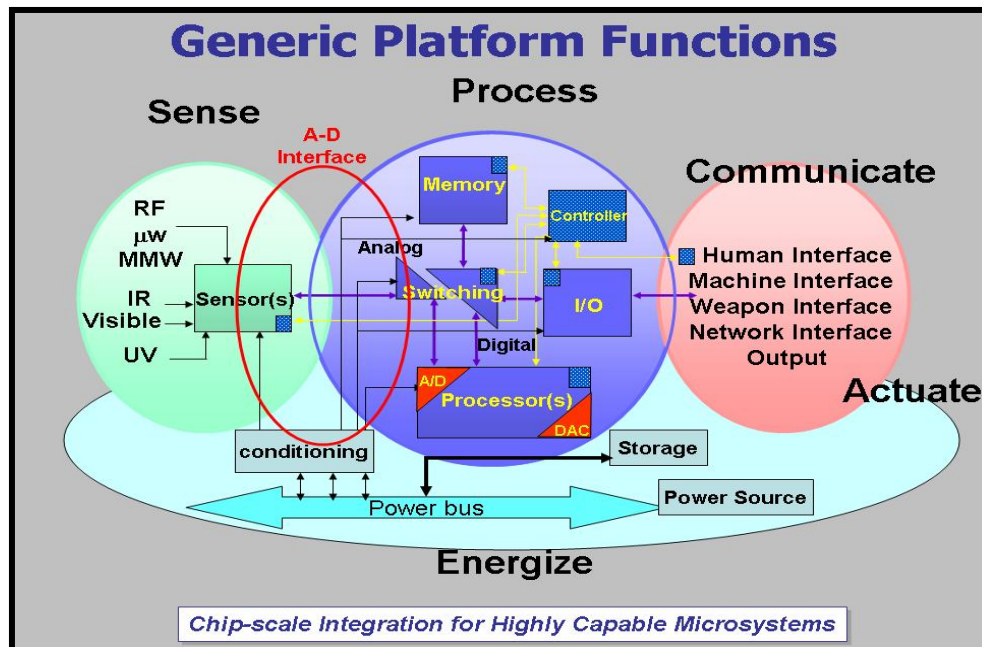
# Future Icons



- **Low-cost titanium to enable routine use (\$3.5/lb military grade alloy)**
- **Accelerate Development & Production of Therapeutics & Vaccines from 12+ yrs to 12 wks**
- **Alternative Energy Sources – Jet Fuel from plants**
- **Prosthetics to enable return to units without loss of capability**
- **Networks - Self-forming, Robust, Self-defending**
- **Chip Scale Atomic Clock to replace reliance on GPS time signal**
- **Networked Sensors – Determine, track, and neutralize elusive threats**
- **Real time language translation to replace linguists (Defense Language Institute, III → IV)**
- **High-productivity computing system – peta scale computer**
- **Air Vehicles - Fast Access, long loiter for military operations**
- **High Energy Liquid Laser Area Defense System as a penetration aid to replace stealth**
- **Space capabilities to enable global military operations**
- **Grand Challenge – Accelerated development of autonomous ground vehicle technology**

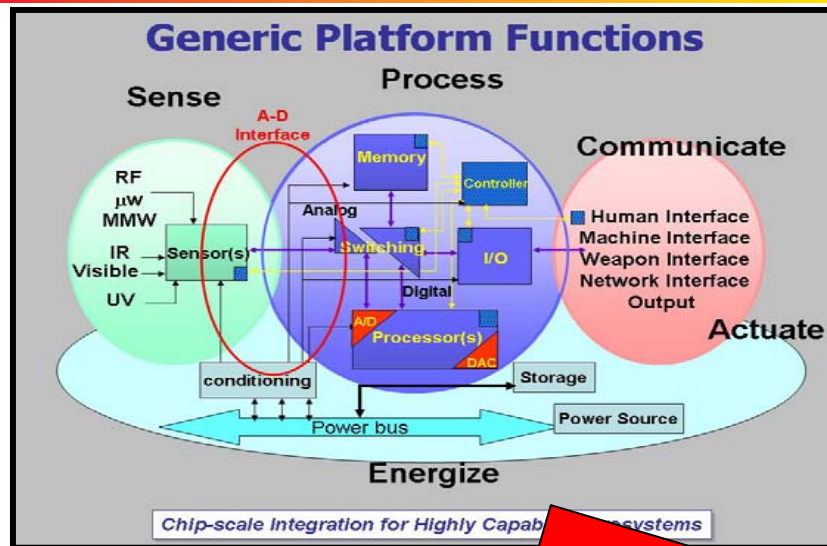
# Opportunities

## Microsystems Technology Advances Enable Future ICONS



- Sense
- Process
- Communicate
- Actuate
- Energize

# Opportunities

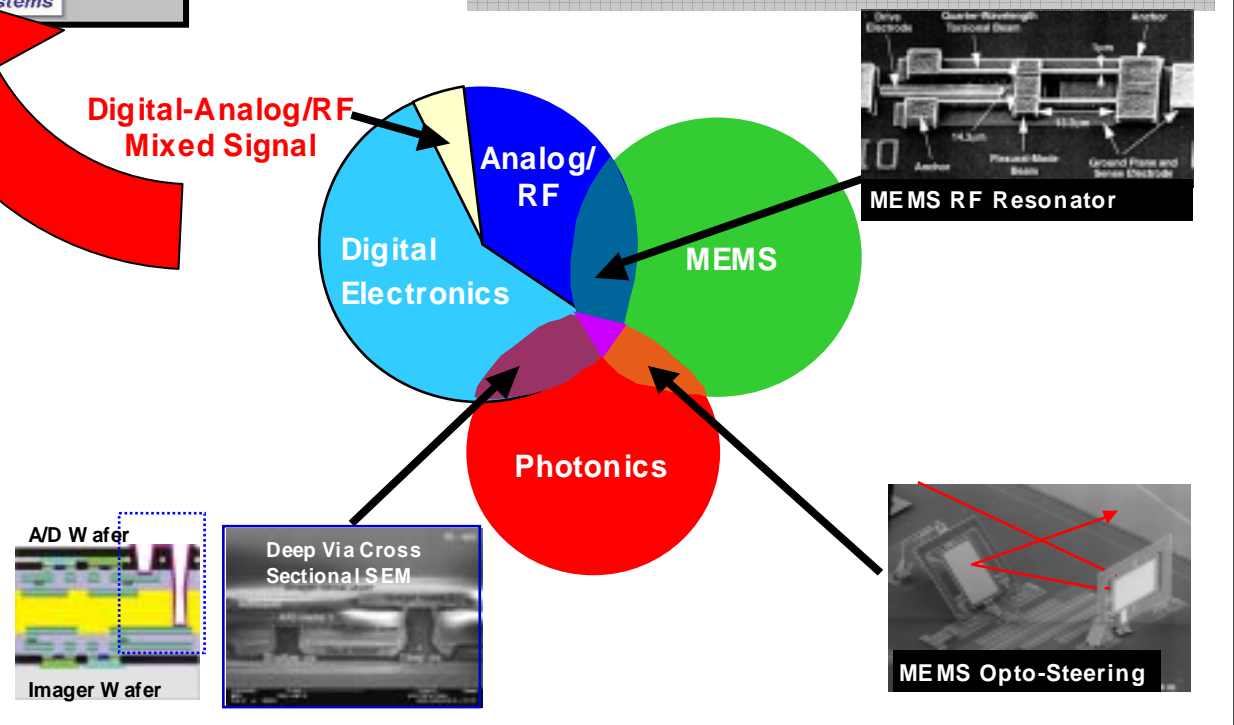


**Applications Create Challenges**

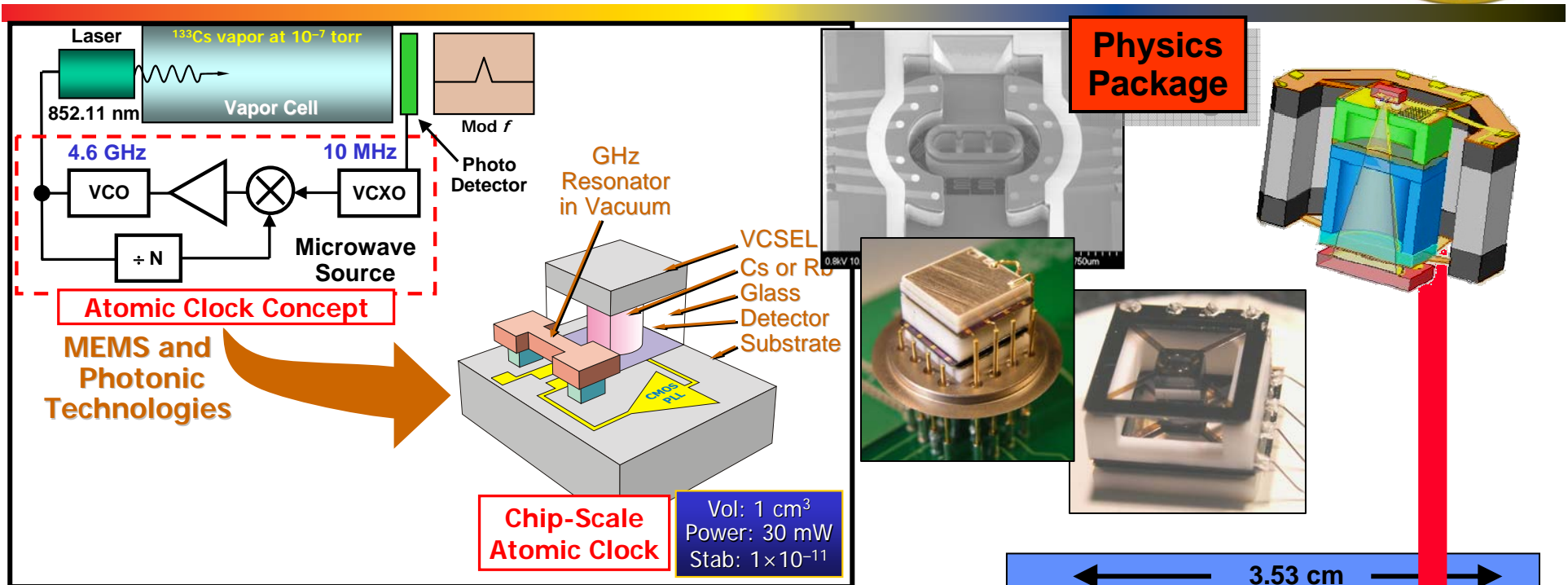
**Innovations Create Capabilities**

## Core Technologies

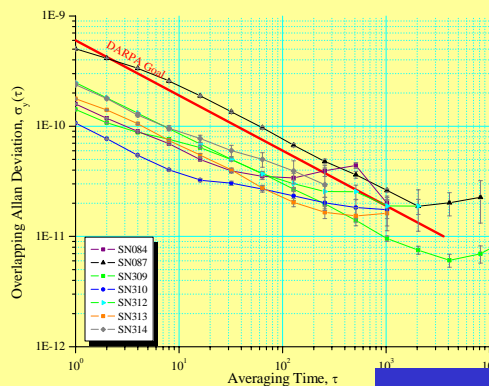
**Digital-Analog/RF Mixed Signal**



# Chip-Scale Atomic Clock



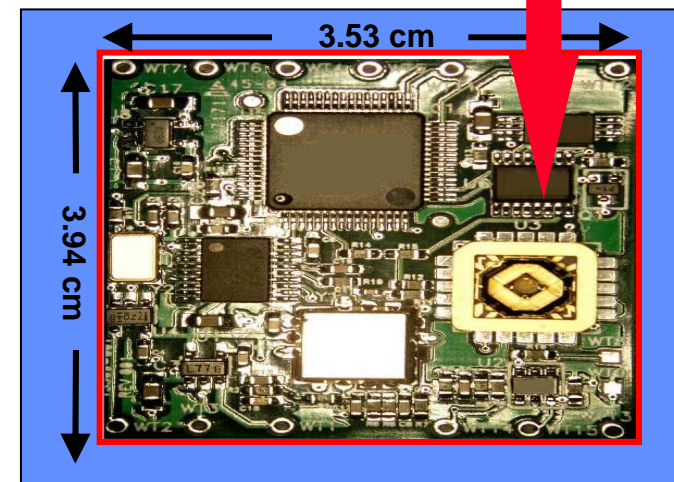
**Stability data**



## Goal:

Miniature, low-power atomic timing and frequency references with

- Allan deviation < 10<sup>-11</sup> over 1 hour (1 μs/day)
- Size < 1 cc
- Power Consumption < 30 mW



**Precision Time for Every Radio and Network Node**



# WASP – Hand Launched UAV



- 2 Color video cameras & GPS
- Weigh: 13 oz.
- Endurance: 30-40 min
- Speed: 20-34 knots

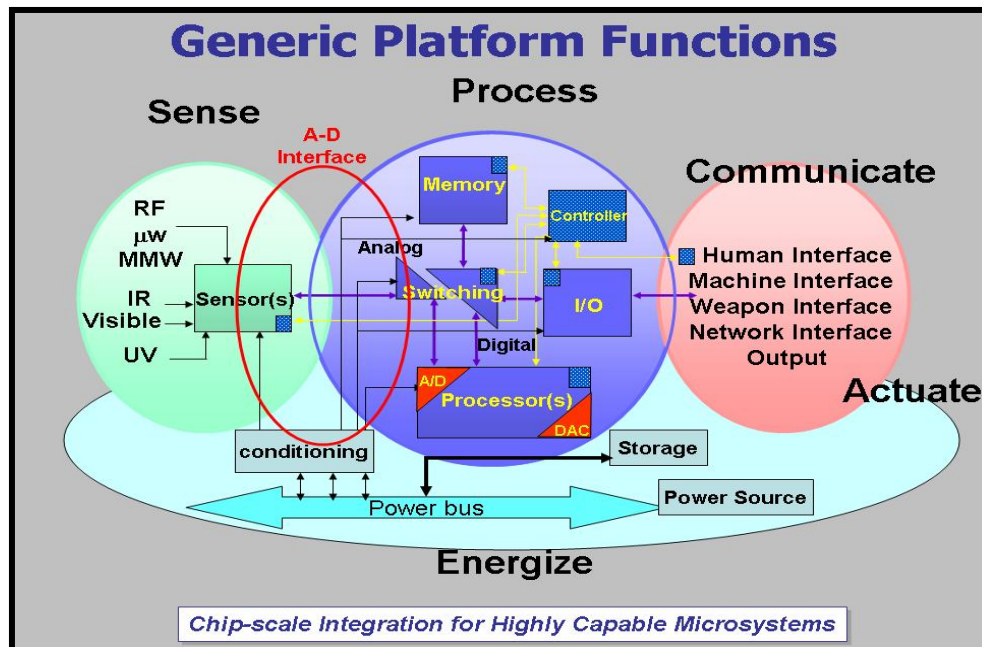
- Hand Launched
- Autonomous Flight
- Auto-Navigation
- Auto-Land



# Opportunities



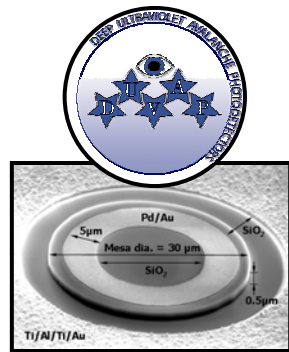
## Microsystems Technology Advances Enable Future ICONS



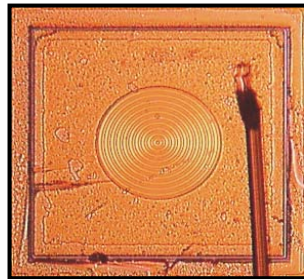
- **Sense**
- **Process**
- **Communicate**
- **Actuate**
- **Energize**

# Sense

## Focal Plane Arrays



**DUVAP**  
(0.5  $\mu\text{m}$ )



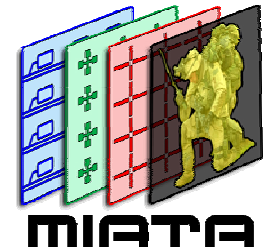
**HOT-MWIR**  
(3-5  $\mu\text{m}$ )



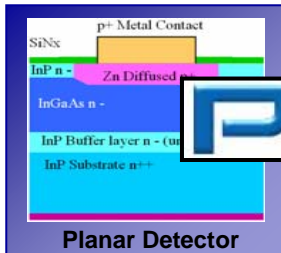
(8-12  $\mu\text{m}$ )



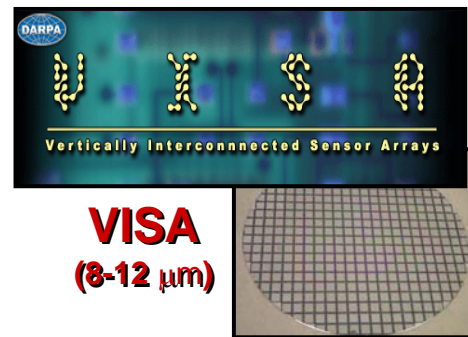
**TIFT**  
(THz)



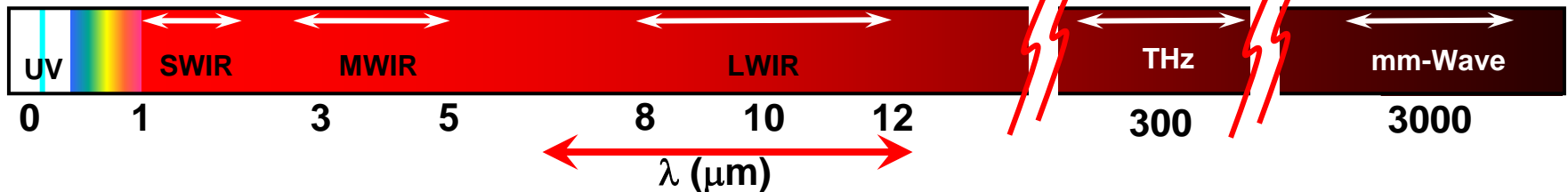
**MIATA**  
(mm-Wave)



(1-2  $\mu\text{m}$ )

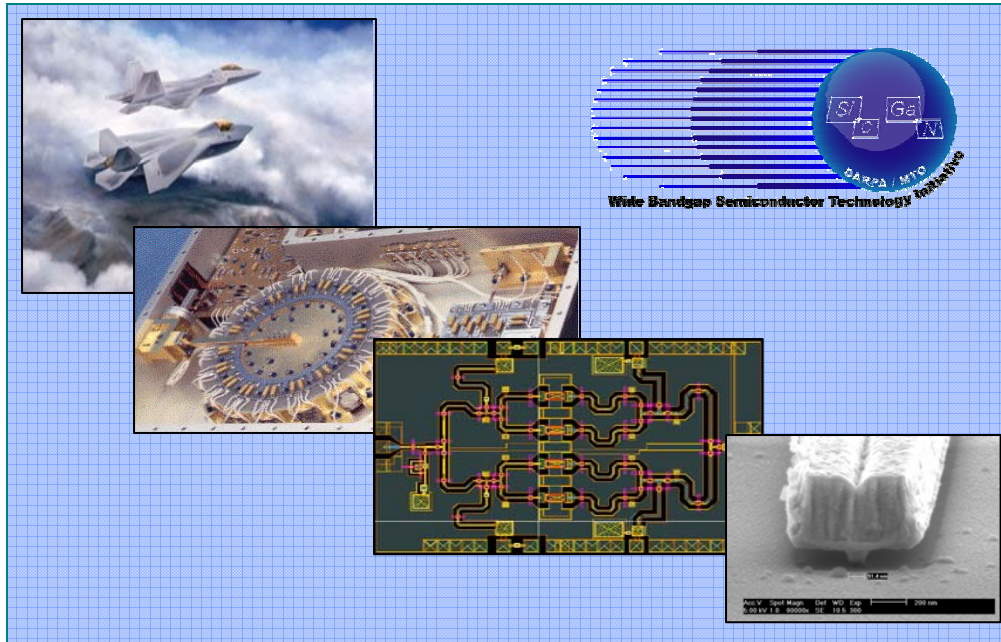


**VISA**  
(8-12  $\mu\text{m}$ )





# High Frequency Semiconductor Electronics Technology

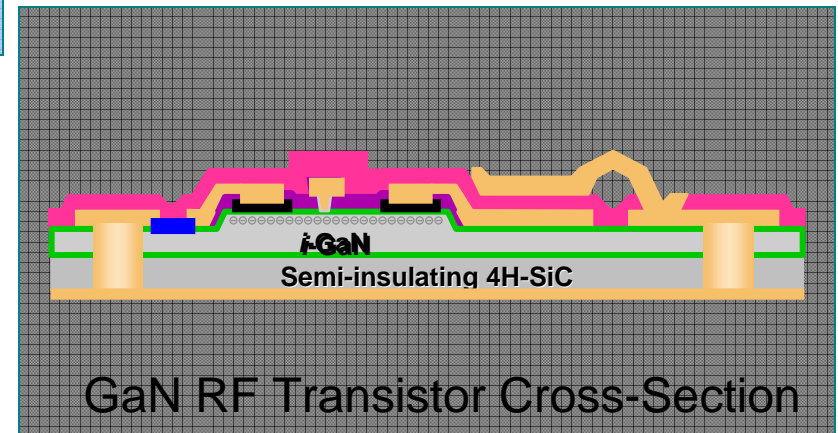


Exploiting materials to achieve reliable, high performance devices and MMICs with

- higher power
- higher efficiency & bandwidth
- superior thermal performance

Achieve rapid insertion into DoD RF systems

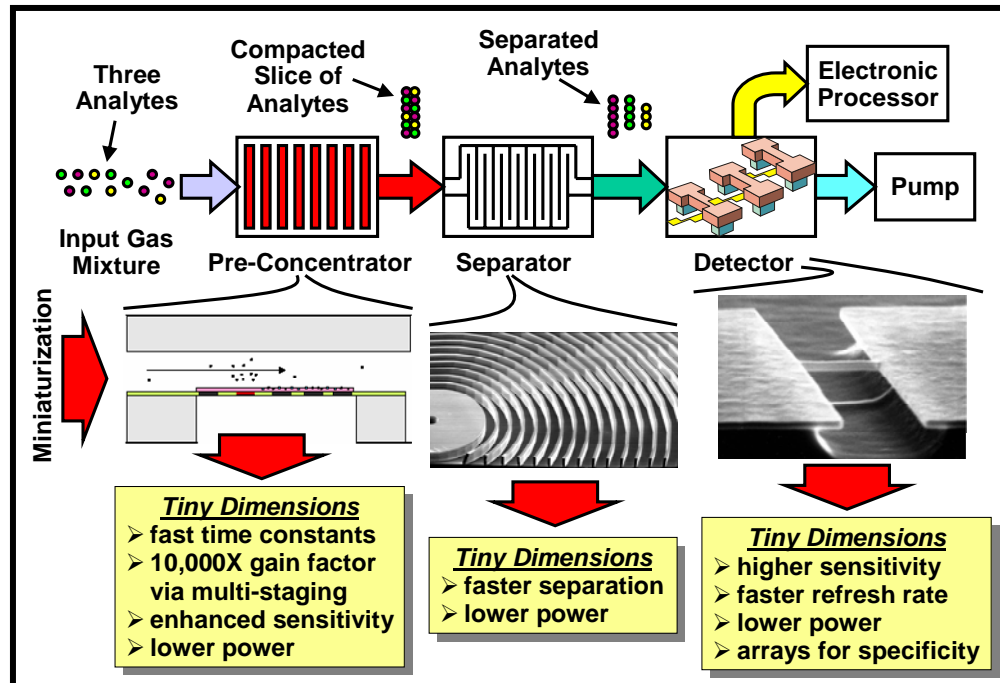
Revolutionizing RF systems performance through increases in solid state amplifier power, efficiency, linearity, noise figure, and robustness



**The Future of RF Electronics for Radar, EW, and Comms**



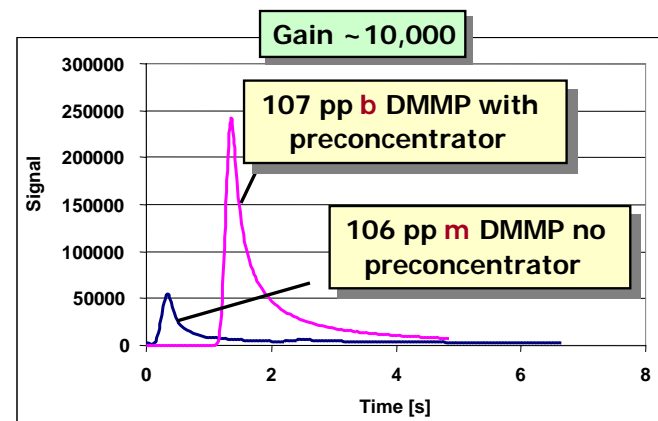
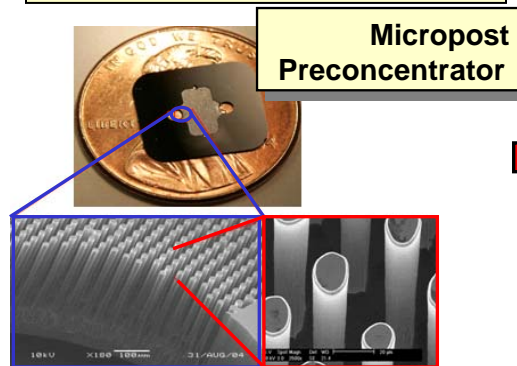
# Chip Scale Gas Analyzers (MGA)



Remote detection of chemical agents via tiny, ultra-low power, fast, chip-scale gas analyzers that greatly reduce the incidence of false positives

- Achieve 4 sec analysis time in <2 cc
- Minimum detectable signal < 1 ppt
- Energy per analysis < 1 Joule

## Preconcentration Gain

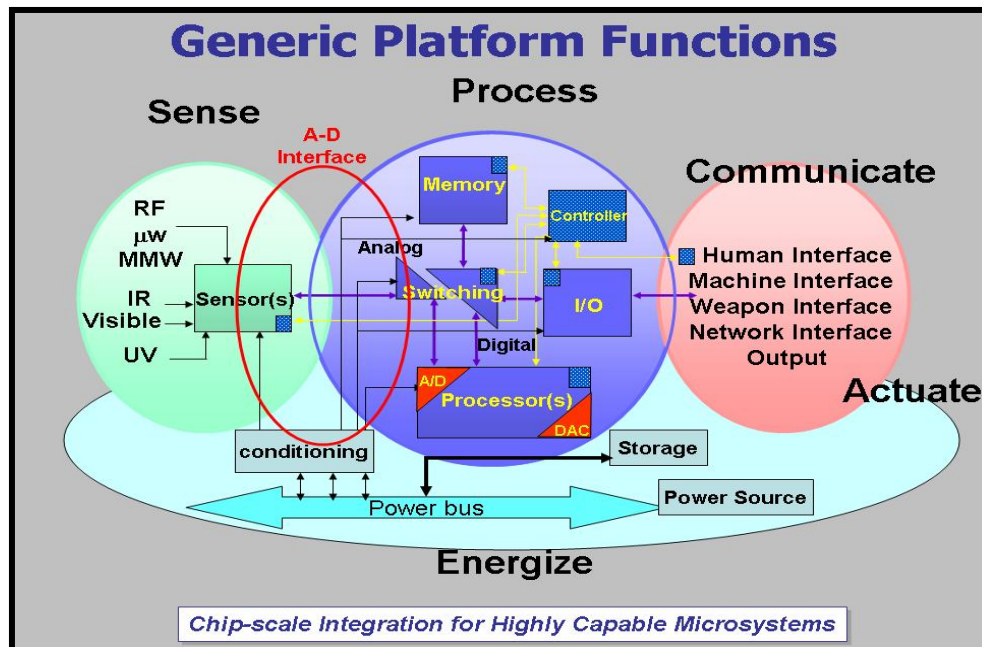


**Gold Standard Chemical Gas Analyzer in a Match Box**

# Opportunities

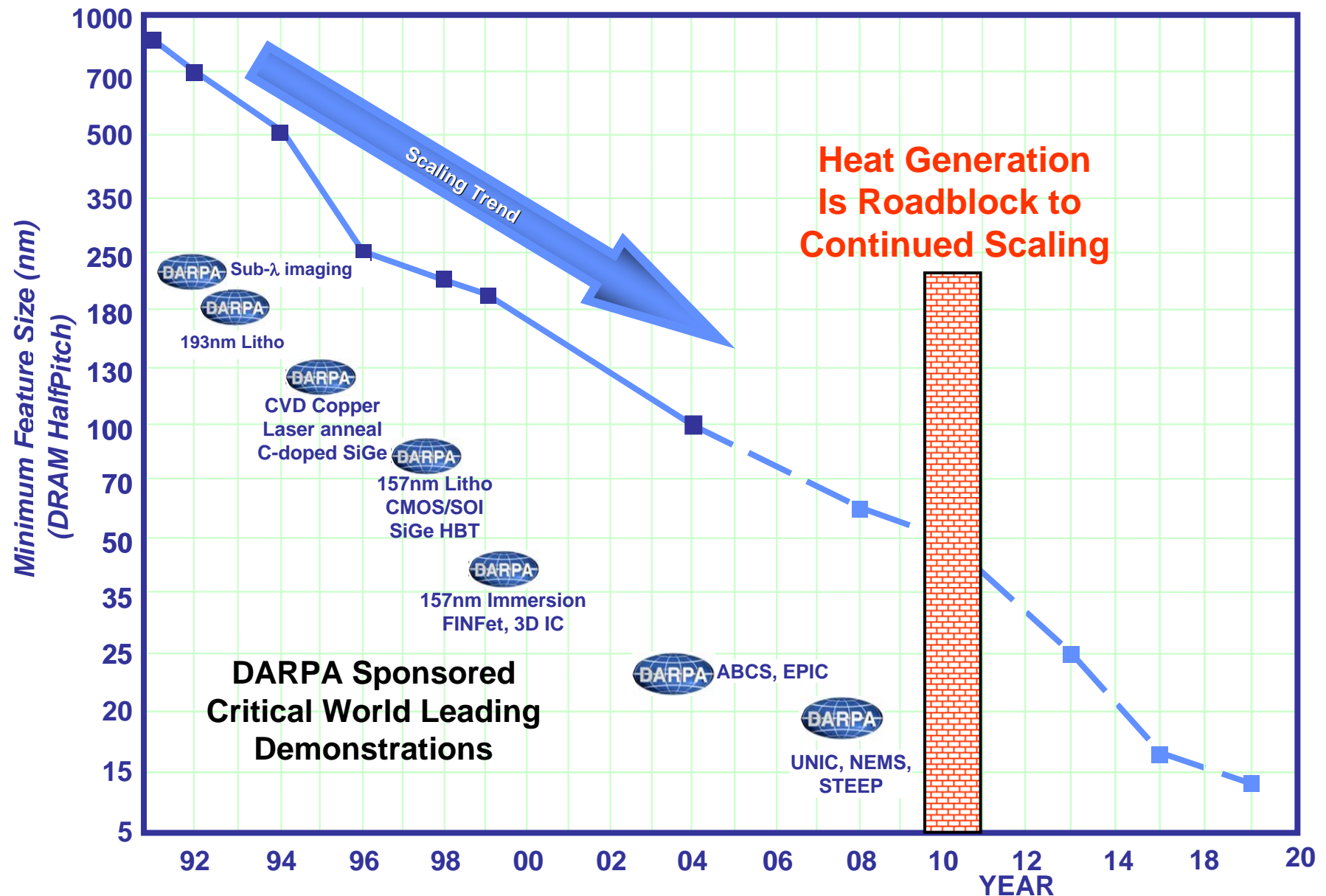


## Microsystems Technology Advances Enable Future ICONS



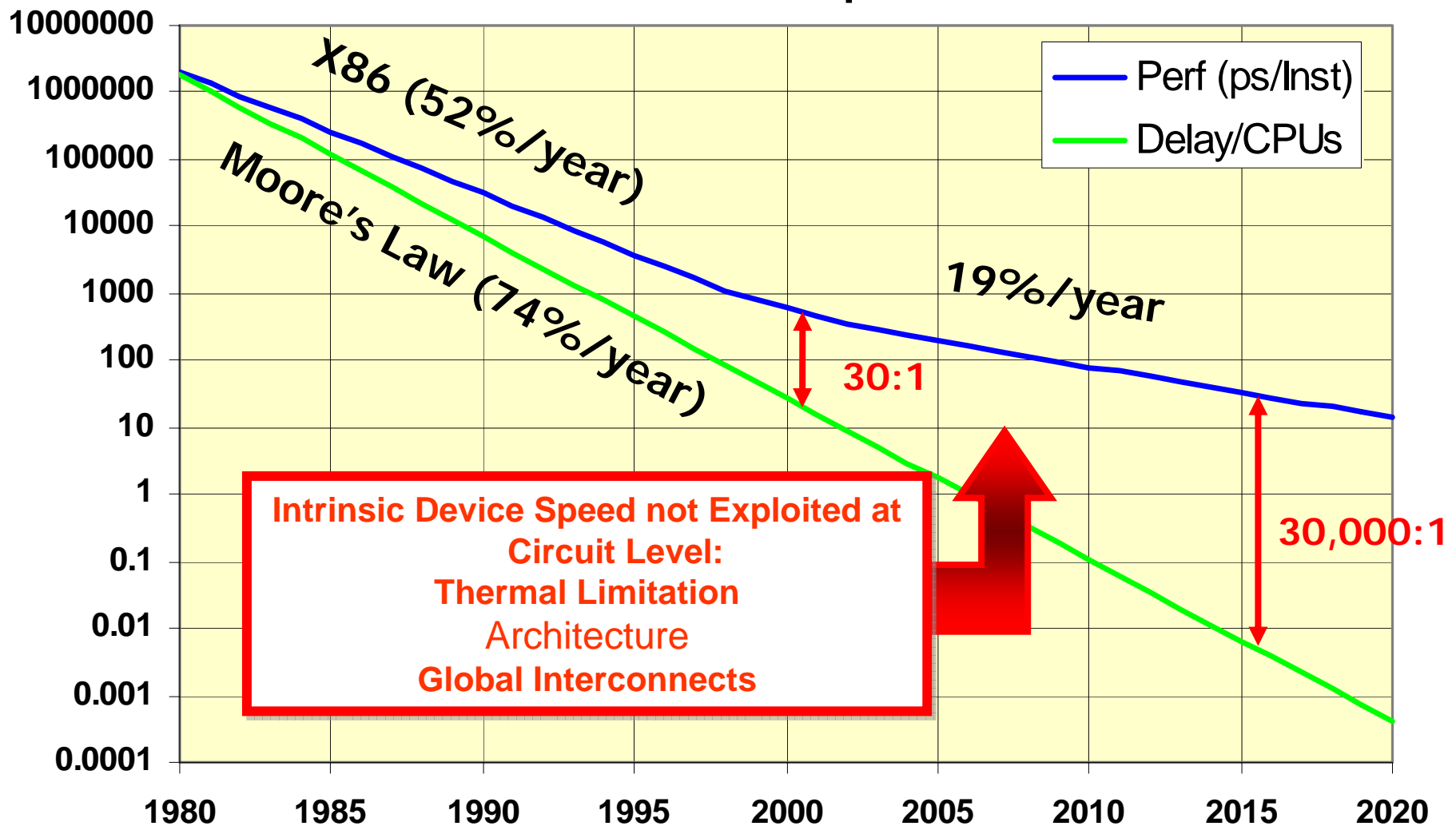
- Sense
- **Process**
- Communicate
- Actuate
- Energize

# Exploiting Moore's Law



# Supercomputer on a Chip

## Intrinsic Transistor Performance versus Circuit Speed

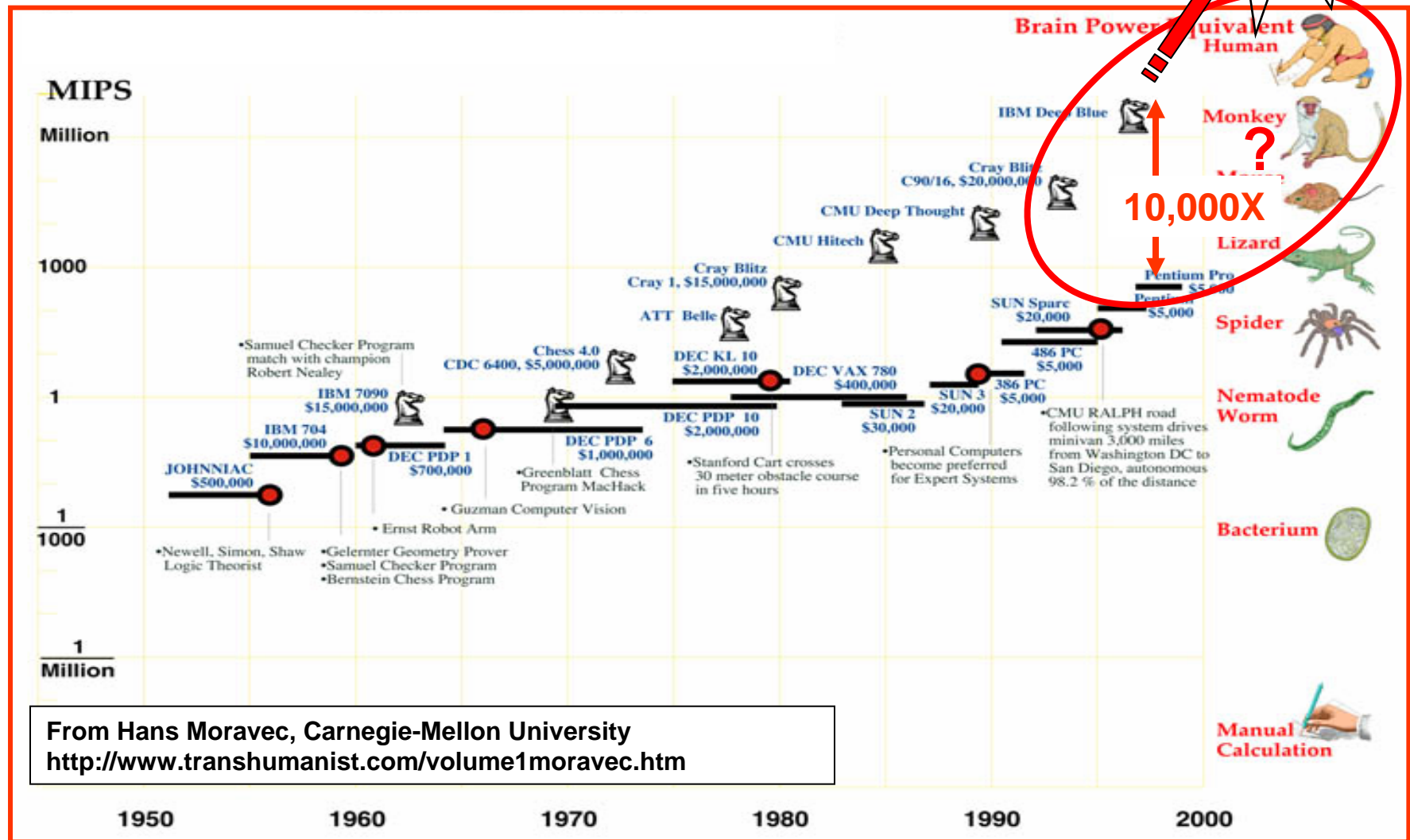


Source: ISAT Summer 2001 Study- *Last Classical Computer*,  
Prof. Bill Dally (Stanford U) Study Lead

# Impact of Supercomputer on a Chip



**HPCS**

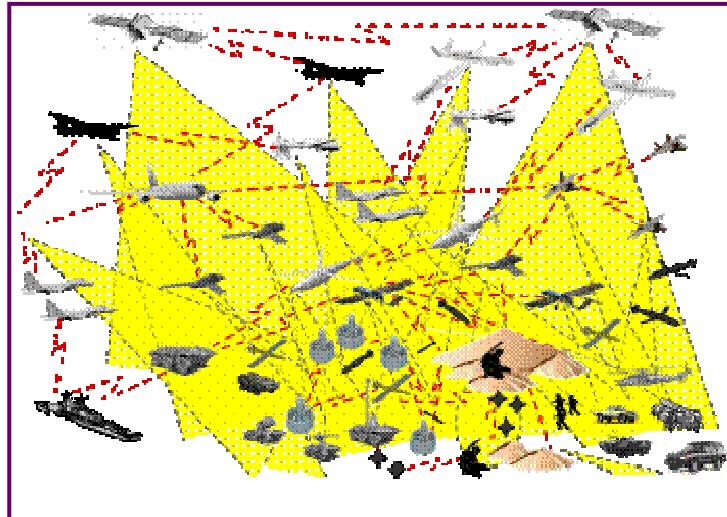




# Cognitive Computing Challenges



**Autonomous Robots**



**Massive Sensor Streams**



**Information Integration**



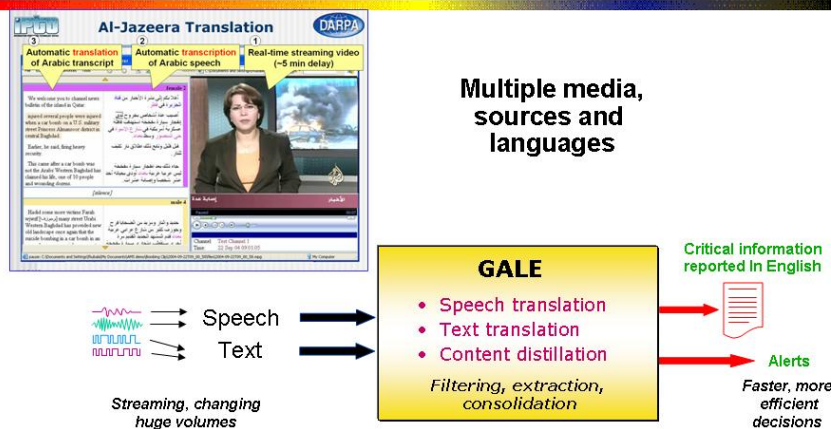
**Rapid Planning & Decision Making**

# Machine Translation

## *In Near Real Time*



### Global Autonomous Language Exploitation



Enable English speaking warfighters and decision-makers to directly absorb and analyze all incoming information in a timely manner regardless of language or medium

Distribution Statement "A" (Approved for Public Release, Distribution Unlimited)

**Real-time two way speech within a limited contextual domain**

**Continuous translation of formatted speech with content distillation**

### Phraselator to TRANSTAC *A Major Leap Forward*



Handheld translation systems for spontaneous two-way speech communications under real world conditions

Phraselator-deployed today



Phraselator



TRANSTAC-Tomorrow's Solution



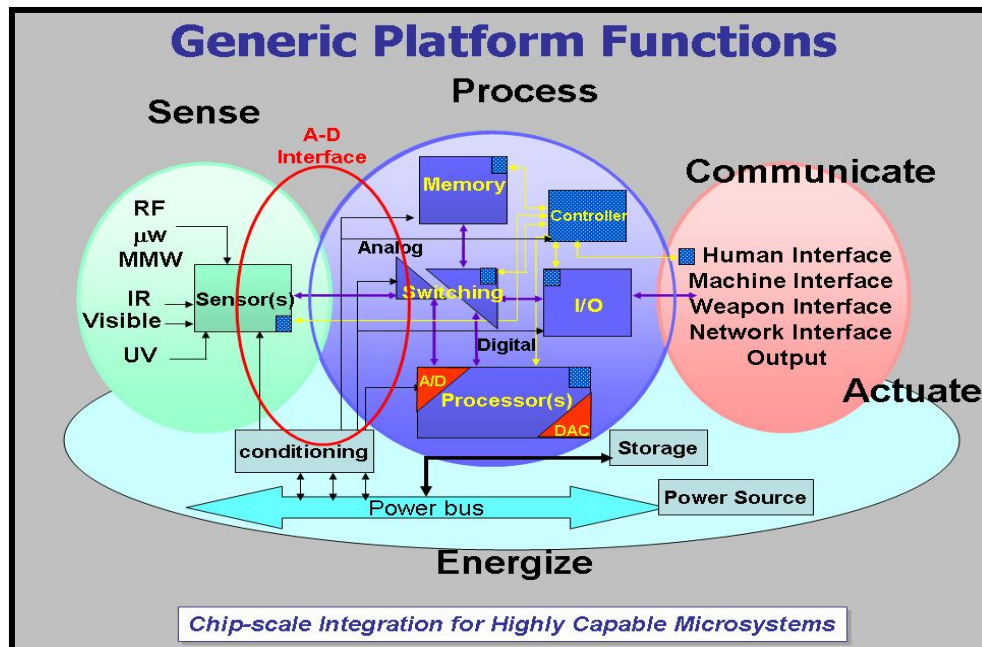
- Begin with limited two-way system
- Constrain the domain
- Enhance performance through iterative testing - robustness to noise, context-driven ASR, etc.

Distribution Statement "A" (Approved for Public Release, Distribution Unlimited)

# Opportunities



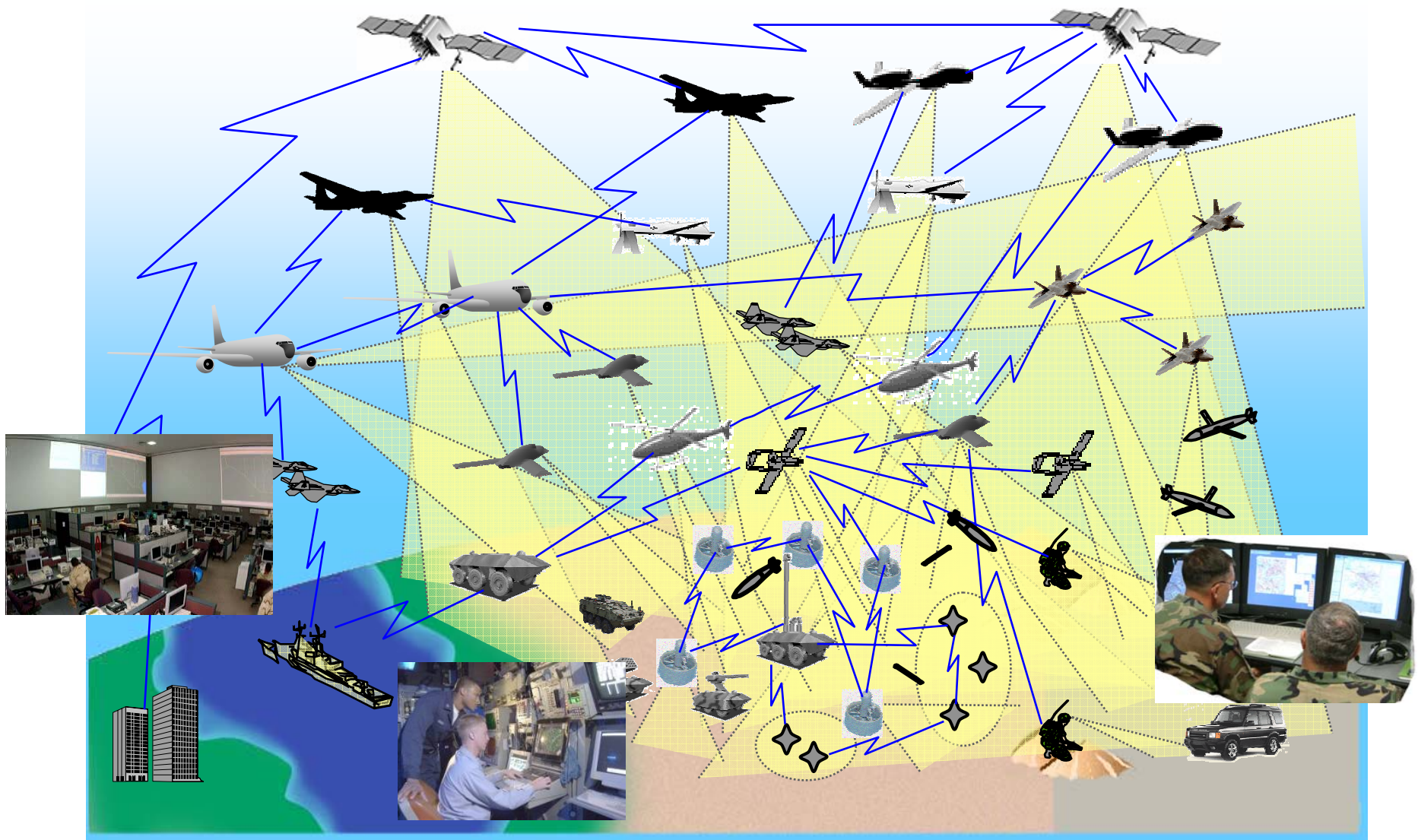
## Microsystems Technology Advances Enable Future ICONS



- Sense
- Process
- **Communicate**
- Actuate
- Energize



# Network Centric Operations



# Military Net-Centric Communications

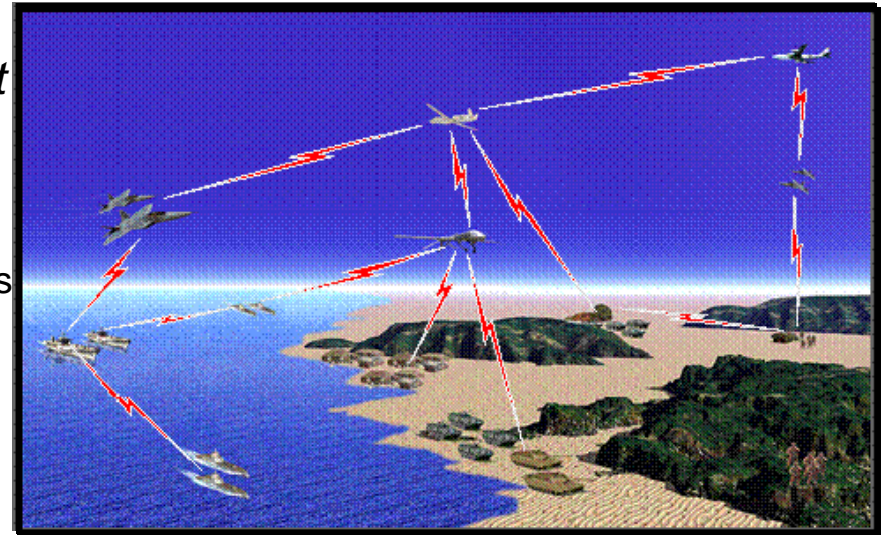
## Challenges



### 1. Network Centric Enterprise

*Strategic and operational level of deployment and warfare*

- Cleared Personnel – TS/SCI
- Links air, ground and naval campaigns
- Engages by operational maneuver and strategic strikes
- Provides information, resources, and sustainment connectivity
- Large C4ISR backbone and infrastructure
  - Rides on GIG and Extensions
  - Can leverage commercial info systems
  - IPv6 early adopter
  - Susceptible to many IA threats

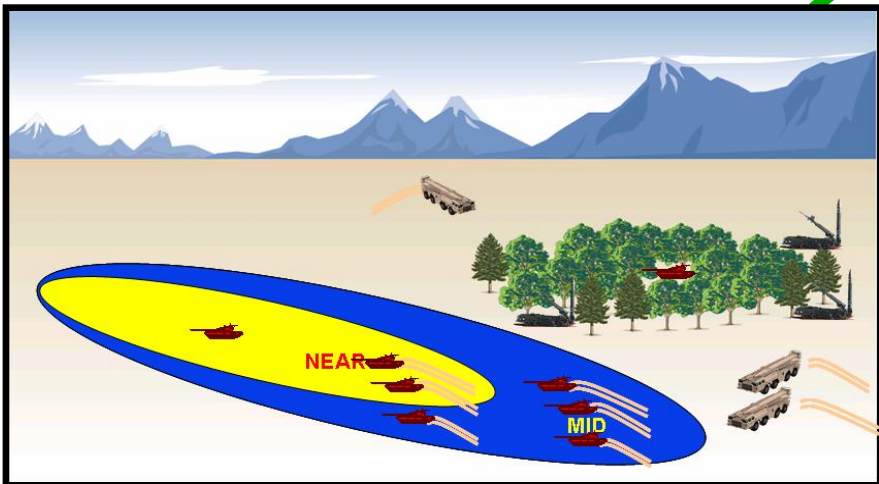


### 2. Network Centric Warfare

*Tactical level of deployment and warfare*

- Uncleared Personnel
- Links effects to targets
- Engages directly with the enemy
- Must be agile, adaptive and versatile
- Minimal, “portable” C4ISR infrastructure
  - Rides on tactical communications
  - Requires LPD/LPI transmission security
  - NCW weapons susceptible to IA attack

3.





# Networked Wireless Communications



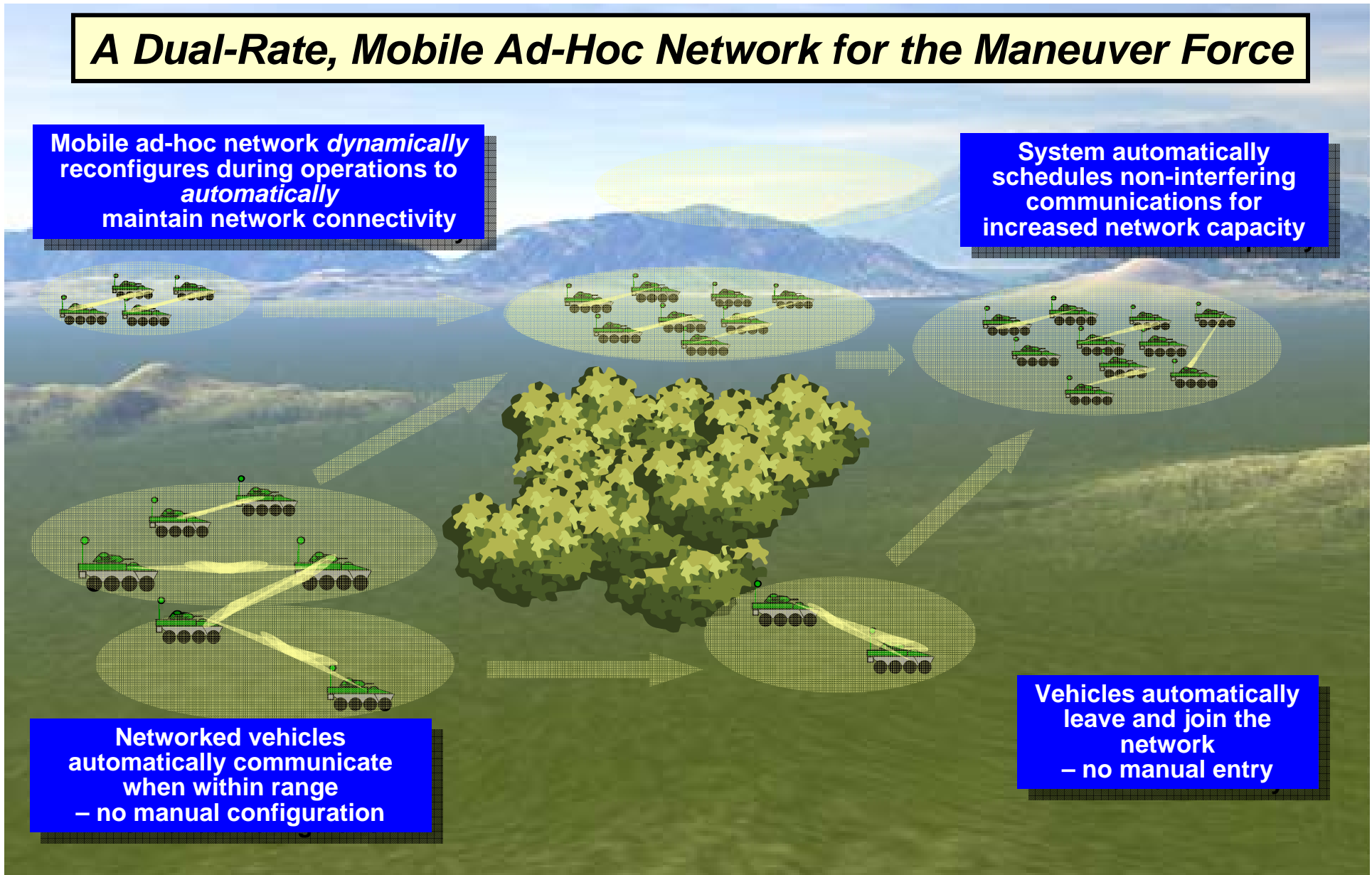
## *A Dual-Rate, Mobile Ad-Hoc Network for the Maneuver Force*

Mobile ad-hoc network *dynamically* reconfigures during operations to *automatically* maintain network connectivity

System automatically schedules non-interfering communications for increased network capacity

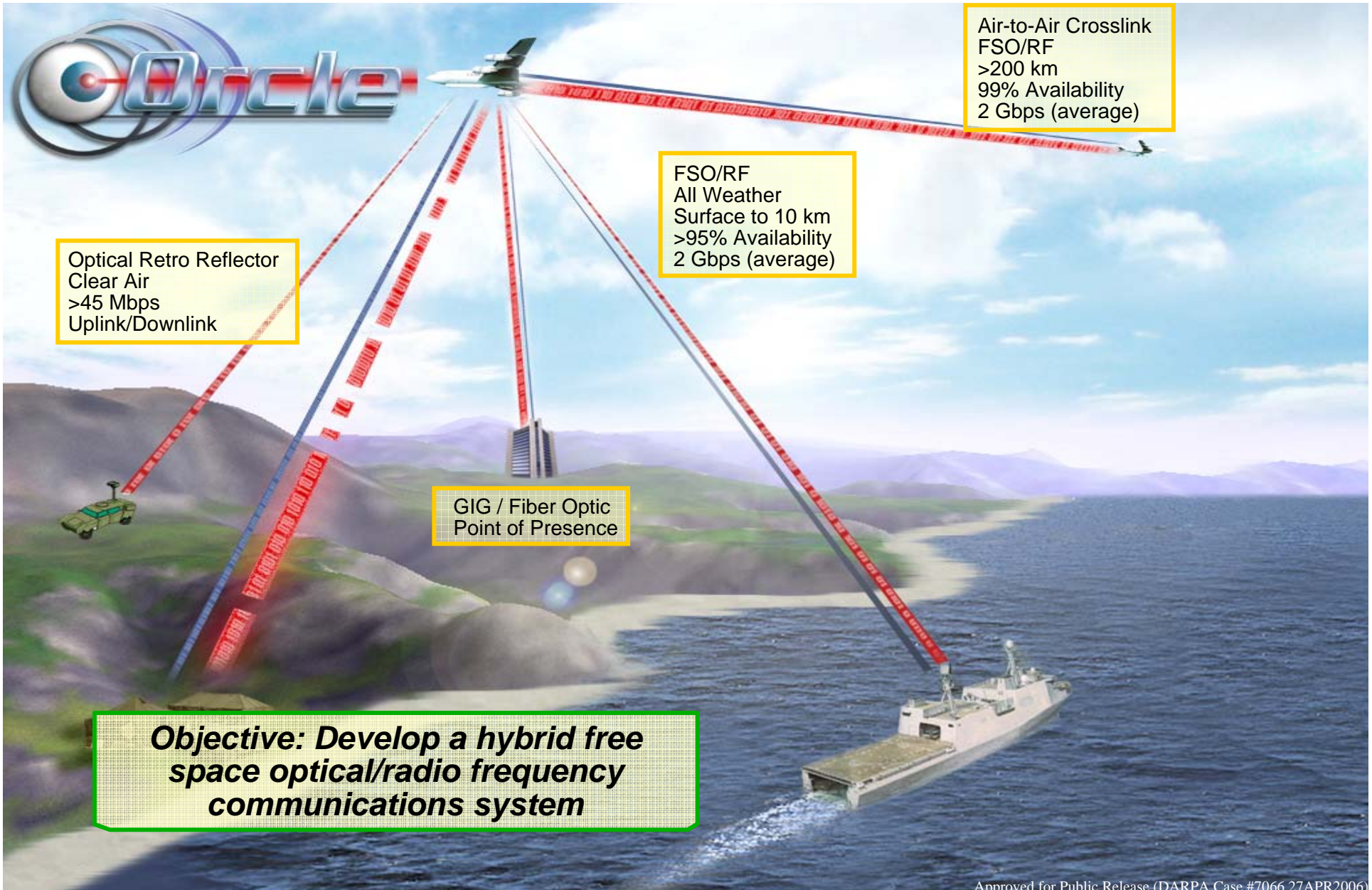
Networked vehicles automatically communicate when within range – no manual configuration

Vehicles automatically leave and join the network – no manual entry



# Optical & RF Combined Link Experiment

*Links to forces fixed and on the move*



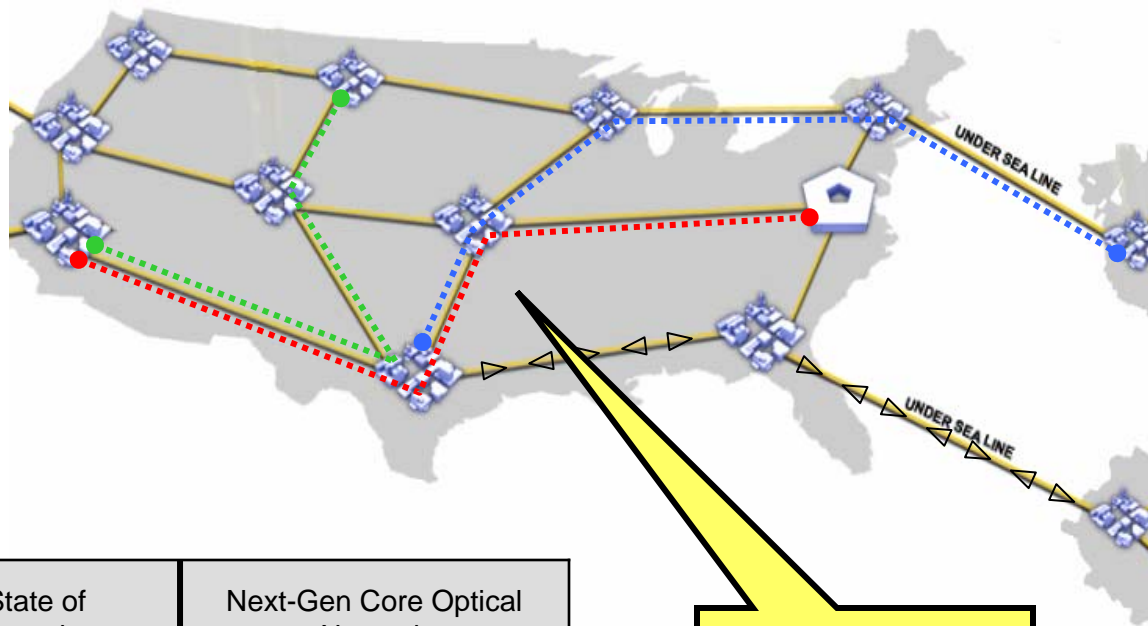


# Next Generation Core Optical Networks



**Goal: Increased Optical Network Throughput with Reduced Latency & Cost**

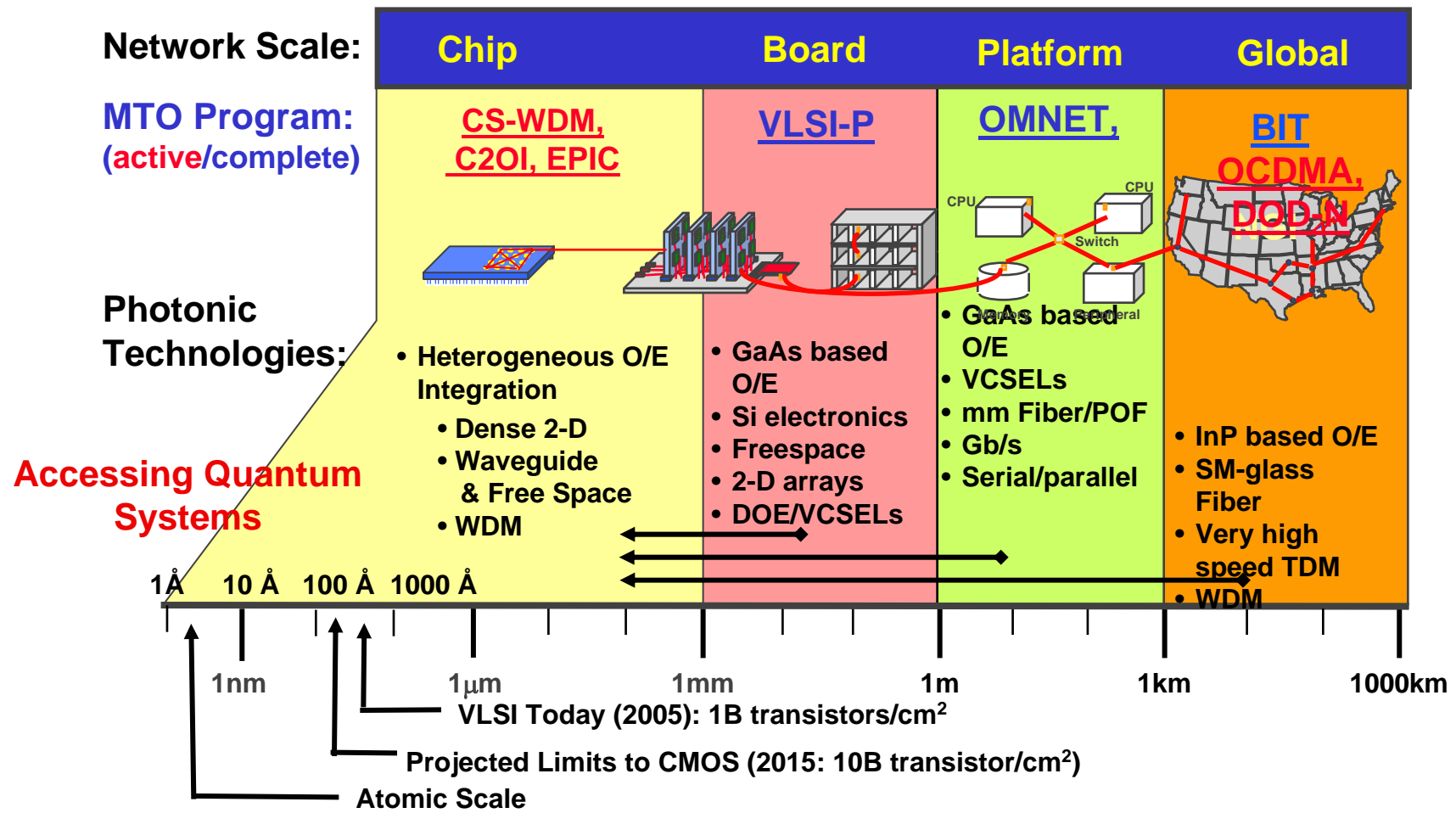
1. Ultra-High-Capacity, Long-Reach Transmission
2. All-Optical Switching and Circuit-Based Grooming
3. All-Optical Bursts or Flow Grooming in Edge Networks
4. Network Control and Management



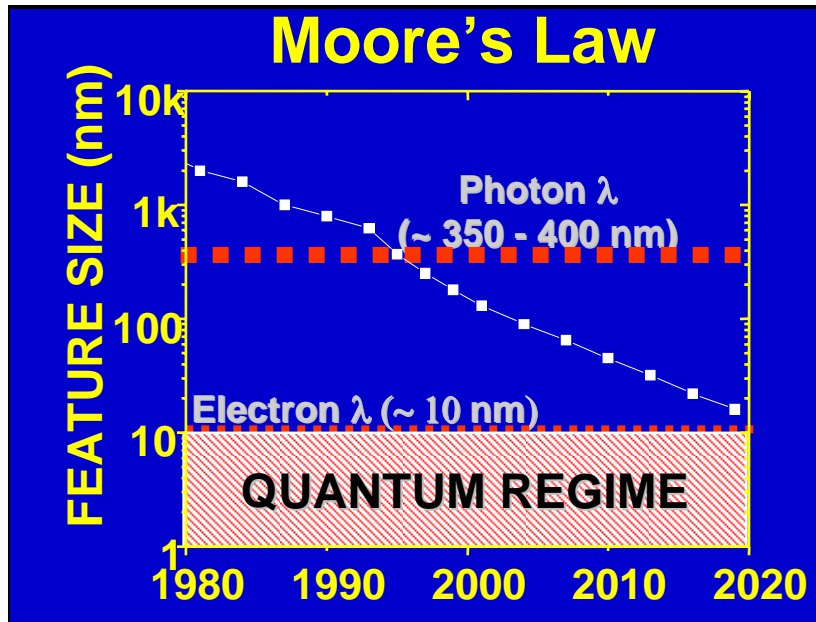
Network Requirement	Today's State of the Art Networks	Next-Gen Core Optical Network
Aggregate Capacity	10 Tb/s	100 Tb/s
Maximum Fiber Capacity	1.6 Tb/s	16 Tb/s
Bit Rate per Wavelength	10 to 40 Gb/s	40 to 160 Gb/s
Speed of Provisioning	Minutes to Hours	< 100 msec
Speed of Restoration	Seconds to Minutes	< 100 msec
Speed of Protection	50-200 msec	< 50 msec

**MTO  
Inside**

# Photonic Data Links

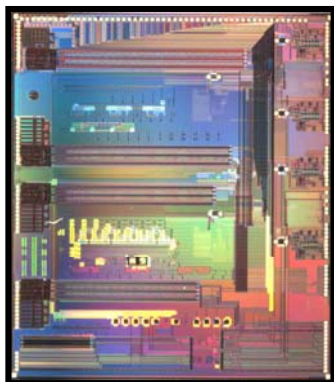
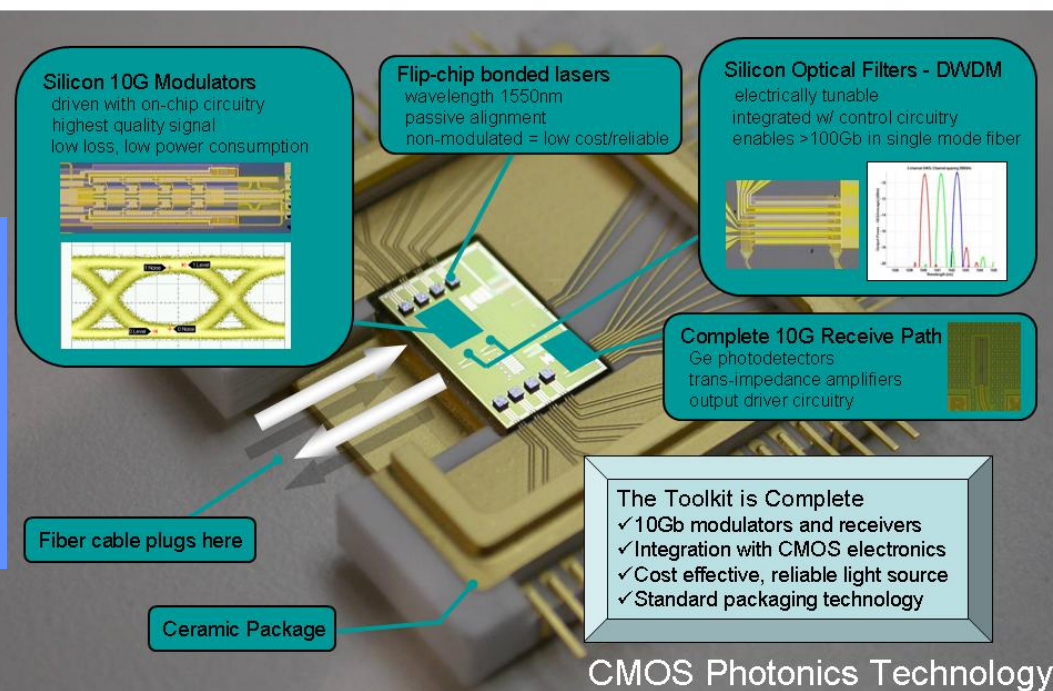


# Electronic & Photonic Integrated Circuits on Silicon



Integration of photonic functions with standard high performance CMOS electronics and fabricated in a standard CMOS foundry

## Optical Data Transceiver Chip in Silicon



8.02 mm x 9.17 mm die

20 Gb/s Transceiver  
4  $\lambda$  x 5 Gb/s  
into single fiber

>100 photonic devices  
+ > 5,000 electronic devices

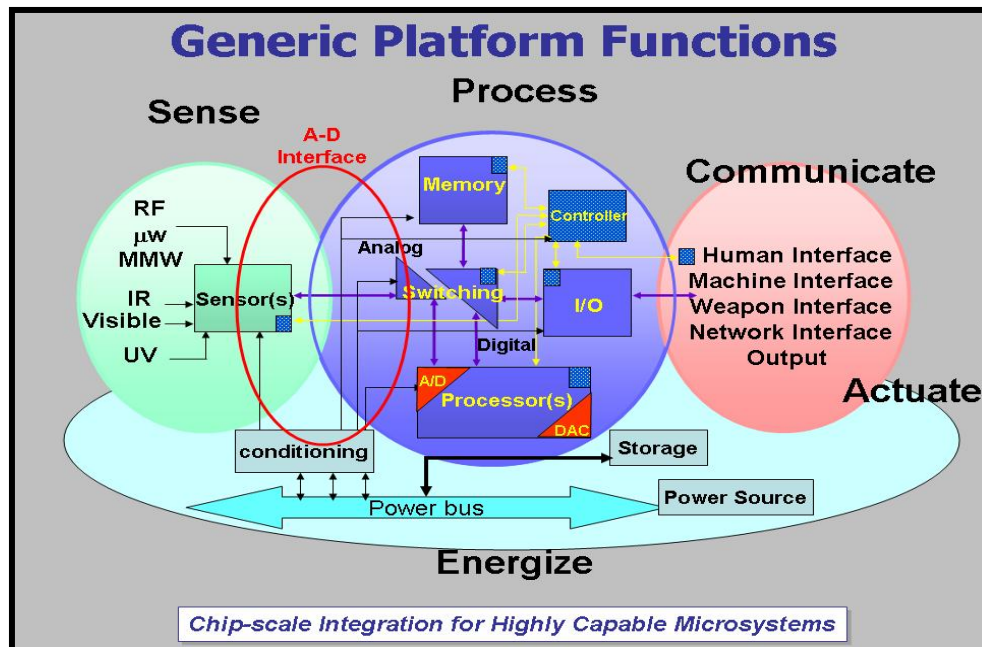


**Seamless Interface between Photonics and Electronics**

# Opportunities



## Microsystems Technology Advances Enable Future ICONS

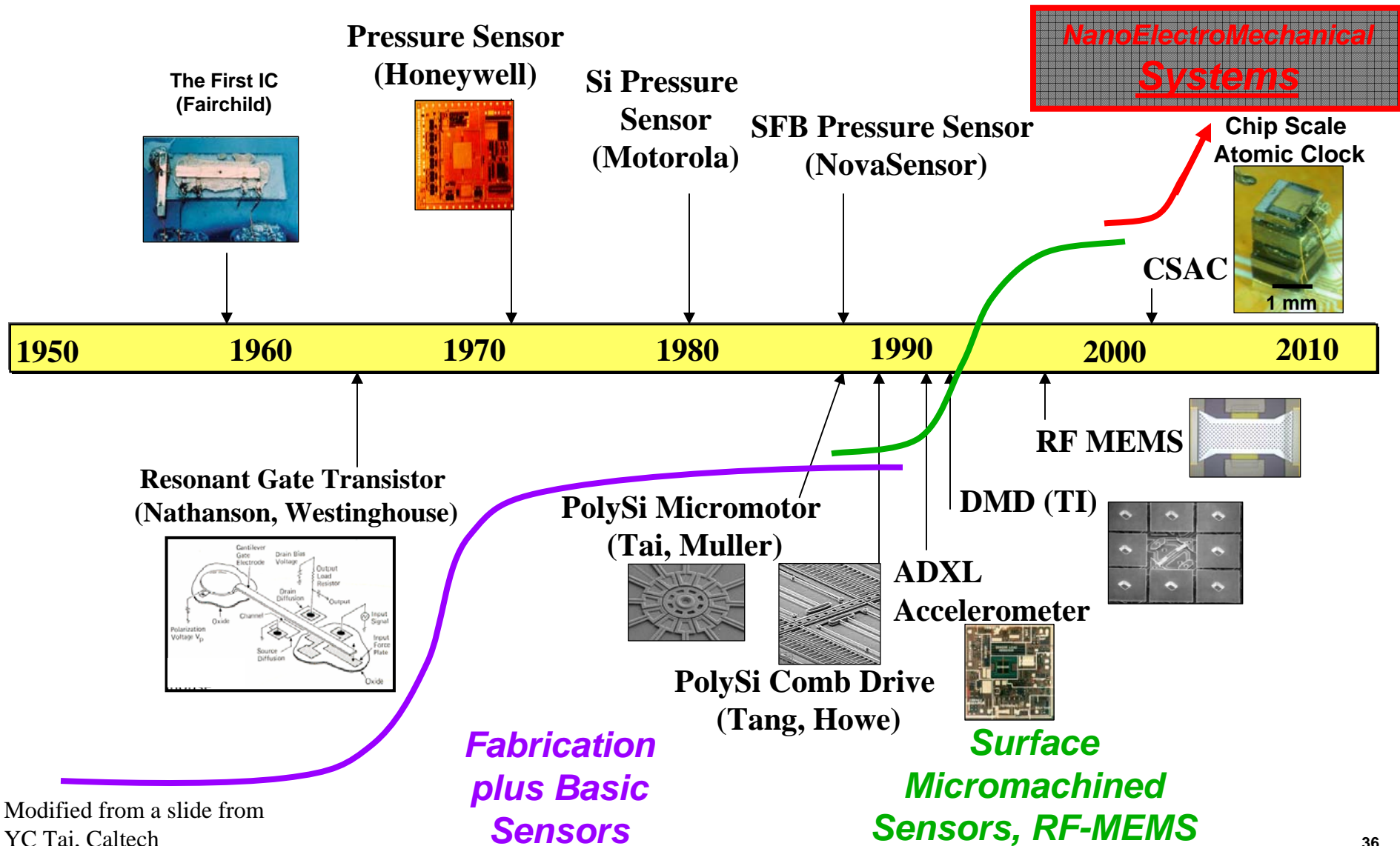


- Sense
- Process
- Communicate
- **Actuate**
- Energize



# Actuate

## Creating the MEMS Frontier

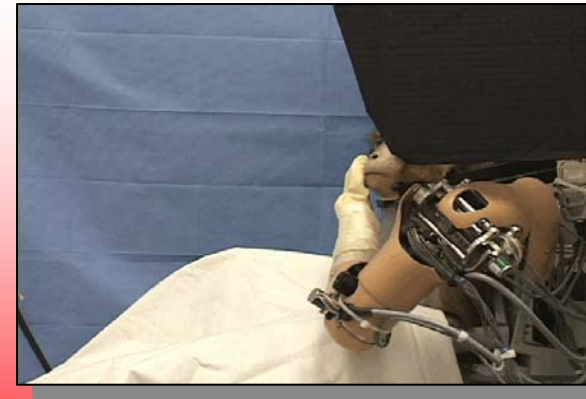
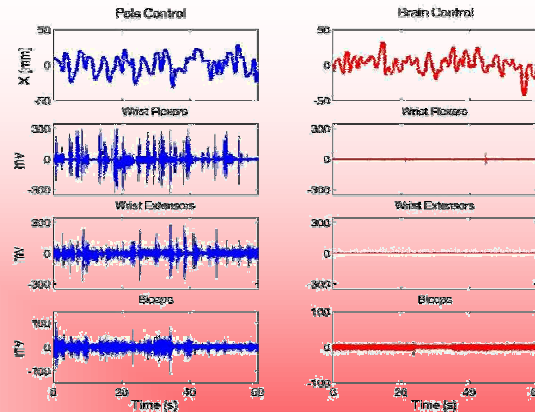


Modified from a slide from  
YC Tai, Caltech

# Revolutionizing Prosthetics

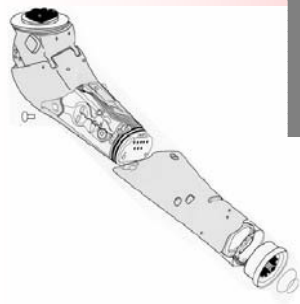


## Understanding the Language of the Brain



*State of the Art:  
Utah arm*

*Fully integrated  
limb replacements*



**Neurally Integrated**

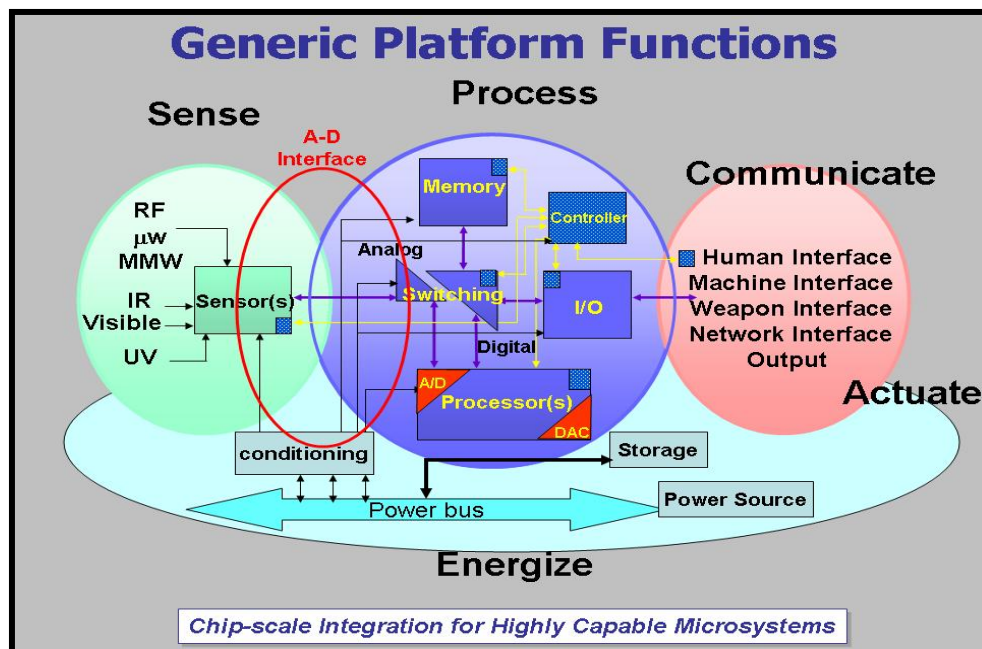
**Mechanically Superior**

- Closed loop nervous system integration
- Full DOF, range-of-motion
- Proportional tactile & force receptors
- Human-like endurance and actuation



# Opportunities

## Microsystems Technology Advances Enable Future ICONS



- Sense
- Process
- Communicate
- Actuate
- Energize

# High Energy Liquid Laser Area Defense System (HELLADS)



## Offensive Targets

- Air defense systems
- Aircraft

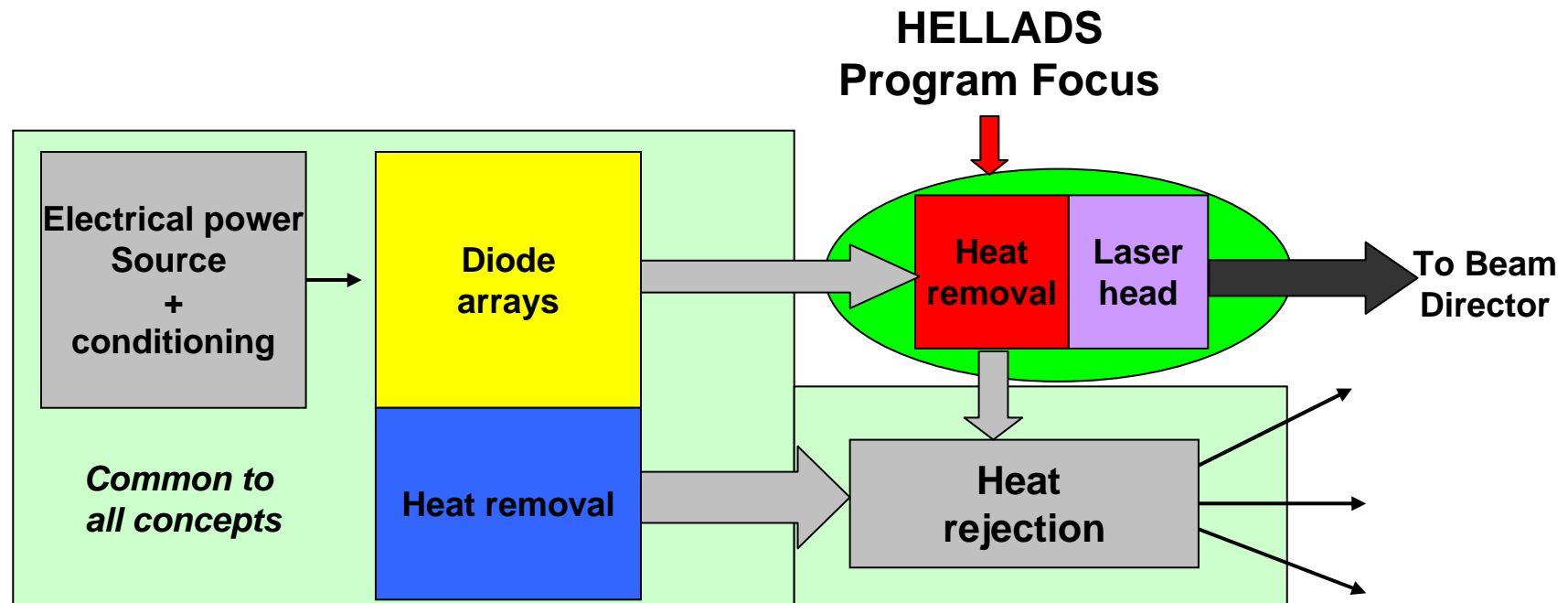
## Defensive Targets

- Cruise missiles
- Aircraft
- UAVs
- Low-altitude missiles
- SAMs



- *Novel Design That Combines the Energy Density of a Solid State Laser with the Improved Thermal Management Qualities of a Liquid Laser*
- *System Goals: 150 kW Laser Output, 5 kg/kW*
- *Enables Laser Weapon Systems Integration with Tactical Platforms*

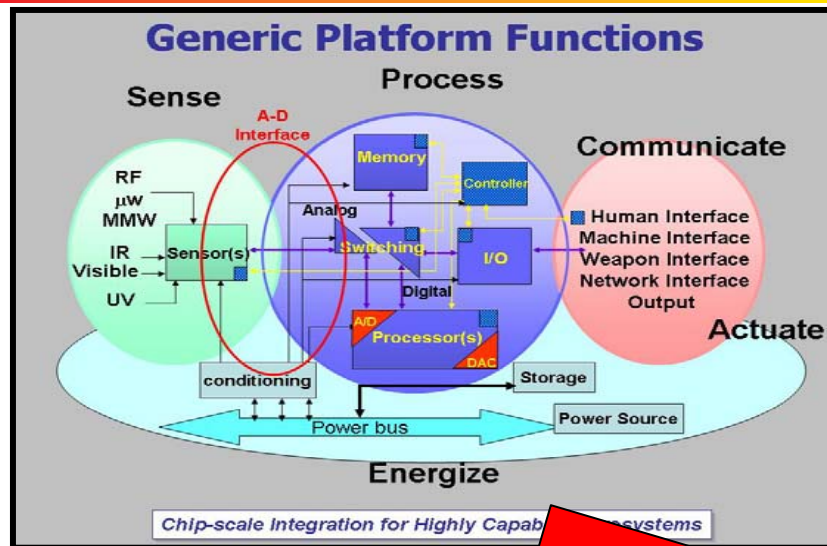
# All Diode-Pumped Lasers Have the Same Basic Components and Issues



Efficiency, power supply, thermal management and beam quality



# Opportunities

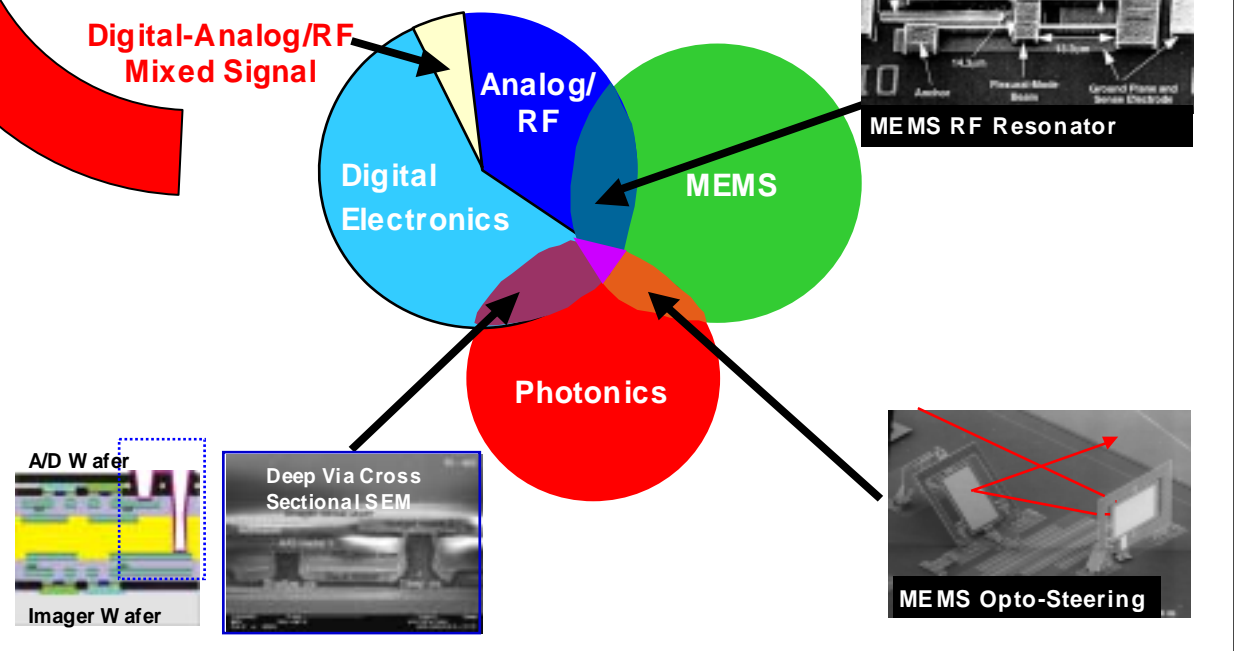


**Applications Create Challenges**

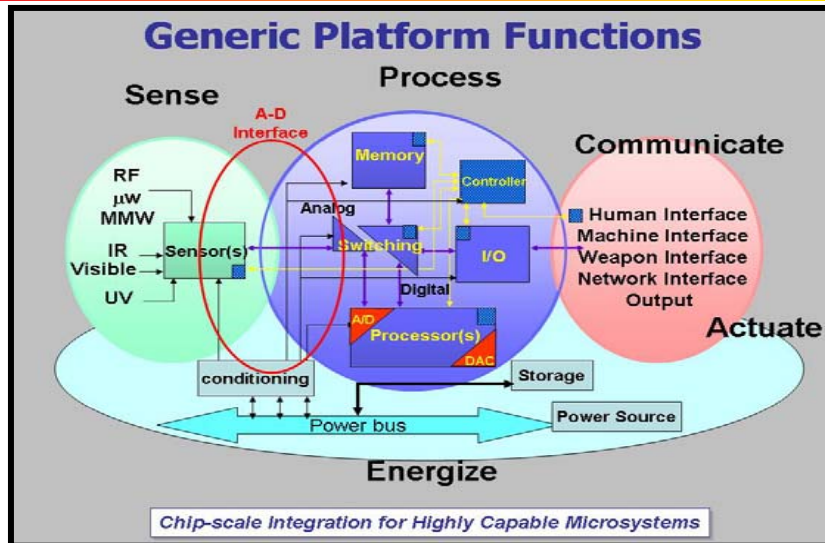
**Innovations Create Capabilities**

## Core Technologies

Digital-Analog/RF  
Mixed Signal



# Future Challenges



## Sensing

- Single photon detection over SW/MW/LW IR
- Room temperature broadband sensing
- Create chip-scale hyperspectral sensing
- Small aperture mm wave/THz imager
- Subwavelength-size pixel focal planes

## Processing

- Eliminate thermal dissipation road block
- Eliminate data throughput and memory access bottleneck
- Overcome the growing complexity in circuit design
- Theoretical limit analog to digital converters

## Communication

- Complete chip scale radios
- Reduced latency
- “internet over RF”
- mm-wave communications
- Coherent optical communications

## Actuation

- Chip scale avionics
- Universal MEMS packaging
- Chip-scale RADAR
- Ultra-stable, lower power timing devices
- Tunable directionality antennas
- Miniature GPS systems
- Micro-scale gas and liquid analyzer

## Energize

- Laser diode bar lifetime and reliability
- Diffraction-limited, coherent high-power diode laser arrays
- Smart power management
- Long endurance micro-power generation

# DARPA



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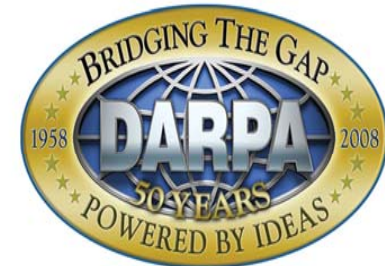
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